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FINAL REPORT

July 1962 - January 1964

FURTHER WORK ON THE USE OF TRACKING TASKS AS INDICATORS OF STRESS

By

Norman K. Walker
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and
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Also issued as Norman K. Walker Associates, Inc., Report No. 10

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October 1964

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They are especially indebted to Lt. Col. H. Williams, of WRAIR, who provided ample laboratory space for their experiments and equipment and participated in many stimulating discussions on stress, and to Dr. Hamilton Mowbray, of APL/JHU, who introduced them to the Auditory Shadowing task and participated in the planning of the main experiment using this stressor.

ABSTRACT

1. Preparing Institution: Washington School of Psychiatry

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3. Principal Investigators: Norman K. Walker
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   Elizabeth De Socio

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Previous work is continued and it is shown that Zero Input Tracking Analysis provides a reliable measure of tracking performance, that tracking degrades severely under the stress of Auditory Shadowing but that the sensitivity of Subjects differs considerably, as might be expected.

It is also shown that Auditory Shadowing appears to produce similar effects to combat, possibly in both cases due to an information overload, and hence Auditory Shadowing may well be a suitable laboratory substitute for combat.

Auditory Shadowing can thus be used to define the sensitivity of any control system to combat degradation using a given group of Subjects, or using a given system to examine the sensitivity of the Subjects.

Mild electric shocks on the other hand were quite ineffective stressors.

This report has also been issued as Norman K. Walker Associates Report No. 10.

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FINAL REPORT

July 1962 - Jan 1964

FURTHER WORK ON THE USE OF TRACKING TASKS AS INDICATORS OF STRESS

PART I

SUMMARY REPORT

by

Norman K. Walker

USAMEDS CONTRACT NO. DA-49-193-MD-2369

FURTHER WORK ON THE USE OF TRACKING TASKS AS INDICATORS OF STRESS

PART I. Summary Report (July 1962 - January 1964)

I. GENERAL INTRODUCTION

This is the final report on the second year of a study funded by the United States Army Surgeon General's Office to investigate "The Use of Tracking Tasks as Indicators of Stress."

The first year's work was funded under Contract Number DA-49-193-MD-2208 through the Institute for Behavioral Research, Silver Spring, Maryland, and was reported in References 1 and 2. During this preliminary stage a new technique for investigating tracking performance - Zero Input Tracking - was devised and investigated which proved to be reproducible, unambiguous, and easily taught to subjects. The subjects would then give consistent and reproducible performance in absolute units, and the degradation in this performance under the influence of a stressor could then give a measure of "stress."

Special analog computing equipment, the Zero Input Tracking Analyzer, or ZITA, was designed and in its latest form is an accurate laboratory instrument which can be adjusted so that any errors due to drift or warm-up are small compared to the Subject's readout of error.

Preliminary experiments with this equipment indicated that alcohol and hypoxia produced - at first - an improvement in performance and fatigue produced by long periods of tracking (one hour) gave some degradation in performance. Degradation was also produced by one night's sleep deprivation but a very large, even catastrophic, degradation in performance resulted from the acute physical discomfort and deep body temperature rise caused by wearing a CBR suit for 1-1/2 hours in an ambient temperature of 85° F.

These results were considered promising but there were indications that the effects produced were strongly dependent on psychological factors.

Work on this phase of the contract was terminated in July 1962 by the exhaustion of funds and the inability at that time to process additional funds through IBR.

The second year's work was funded by USAMEDS through the Washington School of Psychiatry, under Contract Number DA-49-193-MD-2369 commencing November 1, 1962, and the following objectives were laid down:

(a) to improve the ZITA equipment by making it portable and by eliminating the need for various adjustments
(b) to improve the method of training Subjects
(c) to investigate other possible stressors in the hope of finding a simple, reliable, reproducible stressor which could be used by ourselves and

others in experiments in the laboratory and in the field.

(d) to conduct a carefully planned experiment with a number of Subjects using a balanced experimental design, two separate tracking Tasks and two different stressors.

(e) to analyze the results and compare them with other work.

These objectives were accomplished and details are given in this report.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

(a) The Zero Input Tracking Analyzer is an accurate laboratory tool for the measurement of tracking performance.

(b) Tracking performance can be strongly affected by physical discomfort and by mental distraction, but individual Subjects differ considerably in their resistance to stress.

(c) Hence, tracking can probably be used as reliable indicator of the severity of a stress-producing environment for given Subjects and can be used as a method of personnel selection.

(d) Auditory Shadowing, a distraction, produces major degradations in the performance of tracking Tasks. Auditory Shadowing is easy to use in the laboratory or in the field, and can produce very large "stress" effects.

(e) The relative degradation of two acceleration-control tracking Tasks, one with no lag and the other with 1.255 seconds lag, in the presence of Auditory Shadowing is almost exactly the same as the relative degradation of these two types of system in combat. (Tasks A and B respectively)

(f) Hence, tracking Tasks can probably be used as indicators of the severity of combat, and Auditory Shadowing can probably be used to stimulate combat environment for testing systems or Subjects for combat degradation.

(g) An indication of the sensitivity of a tracking task to stress is the absolute error corrected to some standard gain condition.

However, a much more accurate indication is obtained by testing a given group of Subjects on the unknown task, on Task A and on Task B, with and without Auditory Shadowing as a suitable stressor and then studying the relative degradation of the three systems.

We may assign the difficulty index of 1.0 to Task A, and define an environment of unit severity as that which produces a 100% increase in error of Task A. (Note that the severity of a given environment will vary from Subject to Subject.) On this scale, Task B would be assigned the difficulty index of 3.3.

2.2 Recommendations

The conclusions from this report are tentative and should be supported by further work with different levels of Auditory Shadowing on larger groups of Subjects, and on additional types of tracking tasks.

A pilot study should be made in which Auditory Shadowing is used as a stressor, with several tracking tasks, and various popular physi ological measures of stress taken at the same time to provide a direct correlation between the tracking task measurements and the physiological test results.

The Subjects used in the future tests should be subject to a battery of psychological tests to determine whether there is any correlation between these test results and the observed sensitivity to stress. These tests might well be made retroactively on those Subjects already tested.

Future programs where the behavior of Subjects is examined physiologically after exposure to what is believed to be a stressful situation should be examined to see whether a tracking task could not be included in the tests. An obvious case is the examination of air crew after long low-level high speed flights, when by switching out the autopilot for a short time and instructing the pilot to track some distant object, a direct tracking task could be introduced without any additional equipment.

A pilot study should be made on the effect of multiple stressors, such as acute physical discomfort, or a loud noise or vibration, combined with Auditory Shadowing.

3. OUTLINE OF PROGRESS SINCE LAST REPORT

3.1 July 1962 - November 1962

During July - November 1962 no official work was done since contract funds were exhausted. However, plans were made to mount the separate components of ZITA II into a single robust case, apart from the Visicorder, for ease of transport and experimental convenience.

It was realized that further copies of the ZITA equipment would be needed and experimental work was done on a custom engineered replacement for the Philbrick K3V unit, then discontinued and unobtainable.

Experiments were also made in training techniques and on alternative systems of tracking which culminated in the discovery of "flick" tracking. "Flick" tracking is a much more accurate system of control than the "Rubric" method developed previously, but the demands made on the operator were so greatly reduced that it was felt it would probably prove to be insensitive to stress and, hence, of little interest to this particular investigation.

3.2 November 1962 - January 1964

The present contract was let through the Washington School of Psychiatry in November, 1962.

Work immediately began on installing the components of ZITA II in a cabinet for ease of handling, and an improved version - the ZITA IIIa - was constructed for the Walter Reed Army Institute for Research.

Various minor investigations were made to establish:

(a) the fundamental variation of error with stiffness and gain for one particular highly-skilled Subject (S #1)

(b) the effect of the finite width of the display zone of the ZITA II on tracking accuracy

(c) the best method of training

(d) the possibilities and characteristics of Auditory Shadowing as a stressor (see 8.2). (These results were published in an interim report, Reference 3.)

After discussing progress with our Technical Supervisor, Col. Hausman, we decided that sufficient knowledge had been amassed to permit planning the first full experiment on stress. Mr. Fred Shectman, a graduate PhD student in psychology from Washington University, joined the team full-time in June 1963 to plan and direct the conduct of the experiment.

He first made a survey of the literature on stress, and a paper is attached (Appendix 1) showing the extreme variations of definitions of "stress."

Eight Subjects were then trained in "Rubric" tracking on two standard Tasks A and B, and also on Auditory Shadowing. They were subjected to Shadowing and also to mild intermittent electric shocks as an alternative stressor. The experiment is summarized in paragraph 10 and described in detail in Part II.

The results of the experiment were analyzed and the functioning of the ZITA II equipment investigated. It was found that a further improvement was needed since in hot weather small drifts occurred in the output integrator.

Corrections had been made for these in the main experiment, but improved equipment was designed and copies were procured by Edgewood Arsenal and by NAVTRADEVCEN.

During this period, Norman K. Walker Associates, Inc., completed a contract for the United States Army Human Engineering Laboratories, Aberdeen, Maryland, which called for a survey of evidence from World War II and Korea of human operator degradation under combat stress. The results are in excellent agreement with the results of the laboratory tests on Auditory Shadowing. (Refs. 4 and 5)

4. IMPROVEMENTS TO EQUIPMENT

A block diagram of the ZITA II is given in Fig. 1 and a schematic is given in Fig. 6 of Ref. 2.

The main change from the earlier experiments was the standardisation of gain and lag settings and the provision of a fixed cycle timer to give direct readout of the accumulated error over 55 seconds every minute, with a five-second period of unrecorded tracking for reset. The components of the ZITA II were mounted in a single cabinet for convenience in transport and the Visicorder display was later fitted with a hood to fix the subject's viewing distance and to prevent him from being distracted. A photograph of the equipment as set up for the major experiment is shown in Fig. 2 and the latest form of the equipment (ZITA IIIb) is shown in Fig. 42.

Early tests showed that this new assembly was convenient to use but that the alignment of the Philbrick K3V Absolute Value Unit (or full wave rectifier) was critical, and that the standard method of adjustment using a VTVM was not accurate enough for our purposes. With the increasing skill of our operators, who had learned to make perhaps two stick movements per second, the input voltage to the rectifier unit under steady tracking conditions could only be about 1/4 volt, and this must be known to be better than 3%. Hence, the permissible "hole" or dead region of the rectifier cannot exceed 5 or 10 millivolts, and this demands extremely accurate alignment. It was found possible to devise a procedure using the Visicorder itself to align the K3V unit, and also to arrange that an automatic check of the alignment was made every time the timer recycled.

An improved version of the equipment was also developed for the Walter Reed Institute for Research, in which the Philbrick K3V unit (now unobtainable) was replaced by a custom engineered unit. The new unit featured a device to record the total number of stick movements per one-minute run, a timer which could be reset to any point of the run cycle - a great convenience - and also a circuit to count the occasions when the error exceeded a selected limit.

The latter device was found to be of little use in practice and has been omitted from subsequent units.

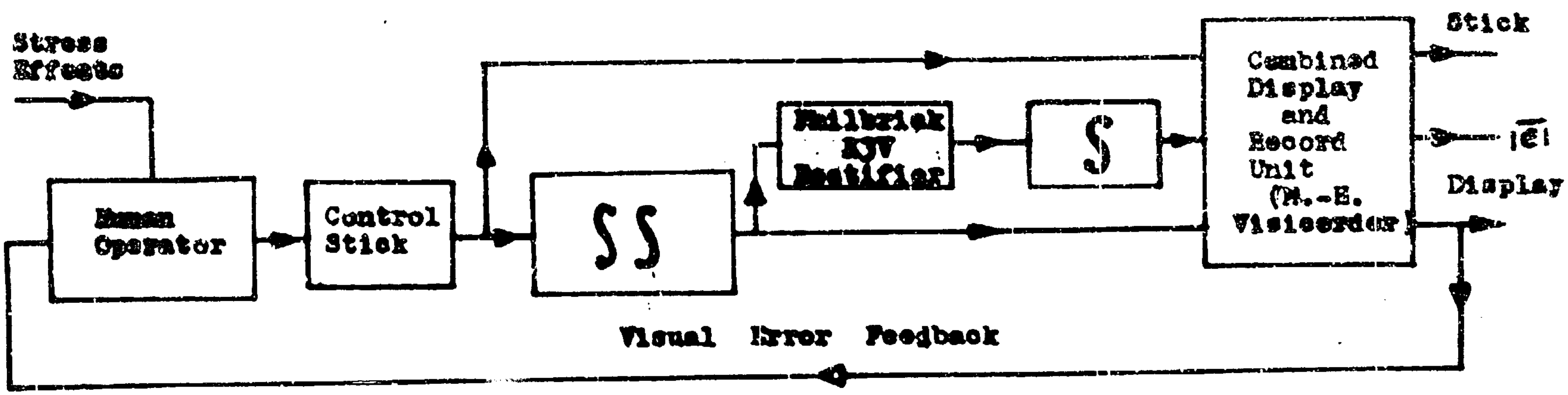


Fig. 1.   Block Diagram for Zero Input Tracking Analyser, Type II.

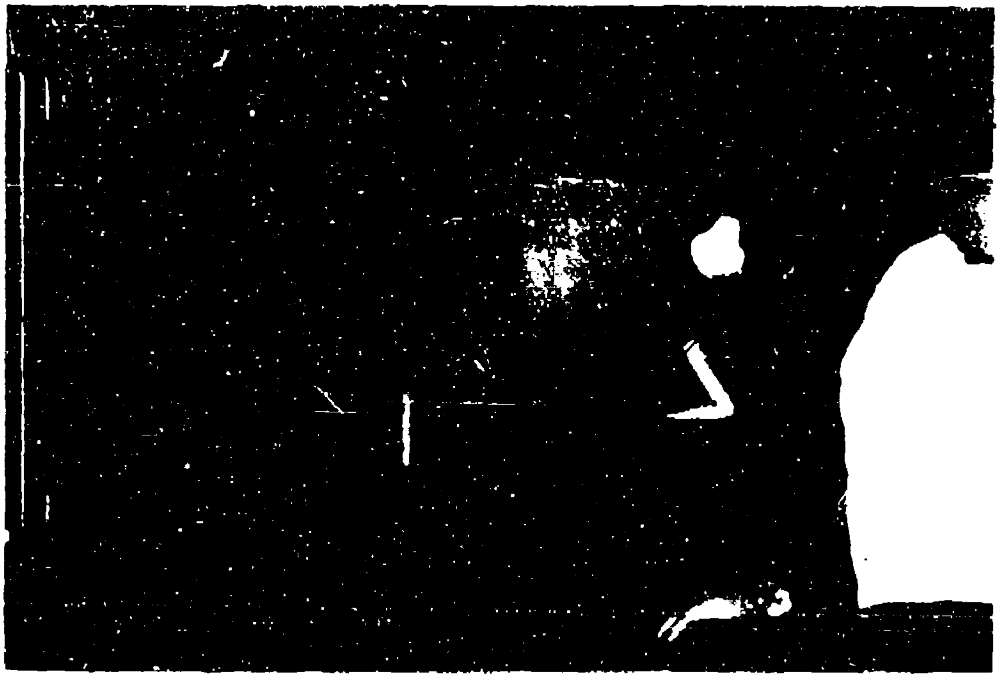


Fig 2. Tracking Equipment as used in the Experiment on Stress. (ZITA II)

Two further ZITA's were built and supplied to NAVTRADEVCEN and the United States Army Edgewood Arsenal. These are known as type IIIb, and include the stick movement counter, and the resetting timer but omit the "crossings" counter as redundant. The ZITA type IIIb also includes a cooling fan to eliminate a slight drift in the output integrator circuit. Once aligned at the beginning of a working day, the ZITA IIIb now requires no further adjustment that day, and is quite unlikely to need other than minor adjustments for months. Fig. 42.

5. THE GENERAL VARIATION OF ERROR WITH STIFFNESS[1] AND LAG FOR SUBJECT #1

5.1 Effect of Direct Gain Variation

Reference 1 gave a general variation of error with gain, no lag, for Subject #1. This was checked again in March 1963 and the resulting points are given in Fig. 3 for a stiffness variation from 8.4 - 915 mils/sec^2 ($= \ddot{A}_{max}$) (gains 1 to 9). The results show the expected hyperbolic curve from the limit of vision - the horizontal asymptote - to a line where error is accurately proportional to stiffness, that is, the frequency response of the Subject tends to become constant. The results are in good agreement with the line given in Fig. 9 of Ref. 2 taken in July 1962, but now that performance has been improved by 20%.

This set of results also showed that previous experience could affect Subject #1's performance. Starting with gain 5 (91.2 mils/sec^2), (point A), Subject #1 was tested at increasing stiffness up to gain 9 (915 mils/sec^2) and then rechecked on gain 5 (B). The additional speed of response necessary to maintain control with gain 9 persisted, and as a result this measurement on gain 5 had appreciably less error. Measurements were then made with decreasing stiffness down to gain 1 (8.3 mils/sec^2). At this point, the operator's response was slowed down considerably, since he now was forced to wait for discernable errors to accumulate before reversing the stick. A second recheck on gain 5 showed that the errors were appreciably increased, owing to persistence of this sluggish response (C).

After further practice, Subject #1 found he could control the system on gain 11, so a further series of tests were made in July 1963 with gain settings 5 - 11 (91.2-2,910 mils/sec^2). These results were in good agreement with the previous measurements.

5.2 The Effect of Gain Variation by Changing the Viewing Distance

According to the theory developed by the authors, the inputs and outputs are only apparent to the Subject as angular stiffness and error, hence, a change of stiffness can be effected by changing the electronic gain, or by changing the distance from the subject's eye to the screen, and no difference should be observed.

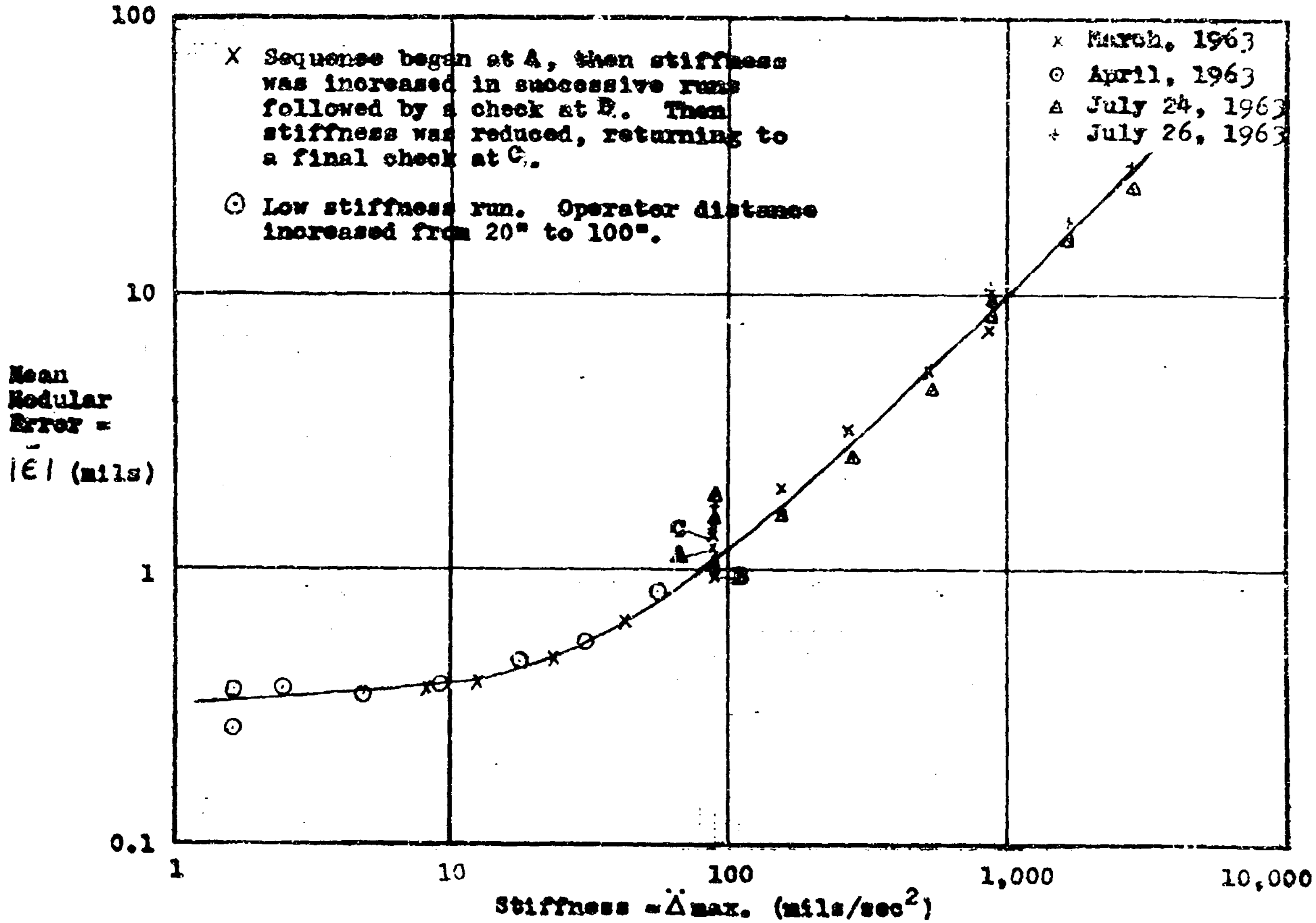


Fig. 3. Standard Variation of Mean Modular Error with Stiffness - No Lag. (Subject No. 1 - N.K. Walker)

Additional tests were run in July 1963 with Subject #1 seated at 100" from the Visicorder display, thus reducing the stiffness for any gain setting by a factor of five. (Special care was taken to illuminate the Zero mark and to balance the equipment.)

The results show (Fig. 3) that over a gain range of 1 to 7 (stiffness now 1.68 - 56 mils/sec^2) there is no difference attributable to viewing distance, per se, and that the tendency to a constant error at low stiffness is confirmed.

5.3 The Effect of Lag at Low Stiffness

It was suggested that whereas at high stiffness the additional difficulty of processing the error information from a lagged system led to a slowed-down response and hence, greater error, at very low stiffness the operator was forced to wait for appreciable errors to develop and thus might achieve much the same results with or without lag.

Tests were made with Subject #1 at a viewing distance of 100" for lags of 0.105, 0.345, and 1.255 seconds. These results are given in Fig. 4 and show that the effect of lag on error is substantially independent of stiffness, and that the asymptote limit of minimum error is probably strongly dependent on lag.

This suggests that whereas with no lag and low stiffness the operator must wait for an appreciable error angle ϵ to develop, with a lag he must detect a combination of ϵ'' , $\dot{\epsilon}$ (error rate) and $\ddot{\epsilon}$ or error acceleration These latter are much more difficult to detect, and hence larger values of ϵ develop.

5.4 The Effect of Lag and Training at High Stiffness

The first results of tracking in this series for Subject #1 are given in Fig. 5, compared with the mean no-error curve from Fig. 1. However, a group of young Army Subjects tested at WRAIR gave better results than Subject #1 with a 1.255 second lag, although they gave inferior performance with no lag.

Subject #1 concluded that he was not fully trained with a one-second lag. After further formal training, he repeated the experimental results in July 1963 and found his errors were reduced and that he could now control the maximum gain settings in the presence of 1.255 second lag. (Fig. 5) However, at low stiffness, the errors were as high as before.

5.5 Summarized Results

The average curve given in Fig. 3 for Subject #1 with no lag is unlikely to change greatly, and can be used as a standardized curve to eliminate the

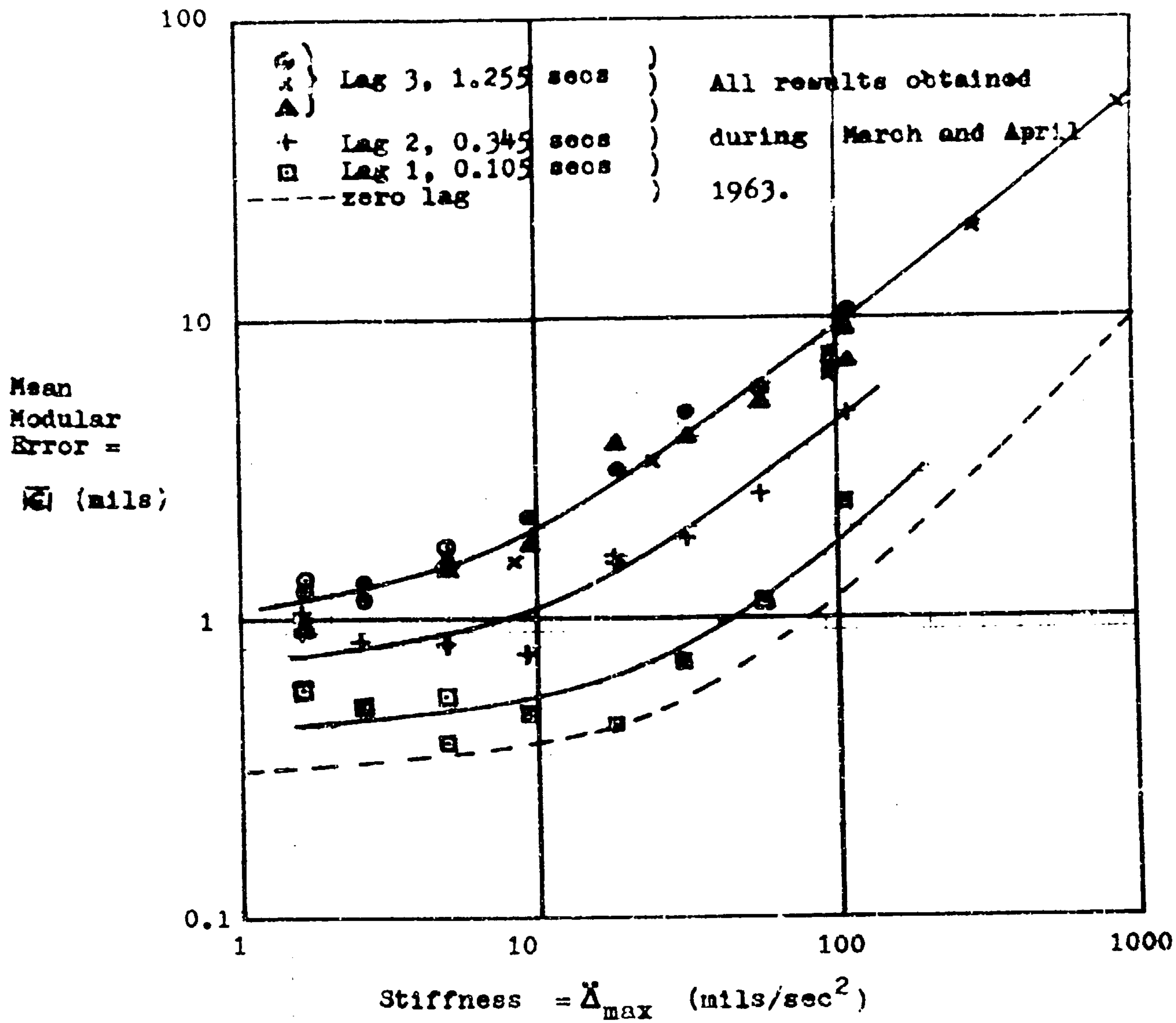


Fig. 4. Effect of lag at low stiffness

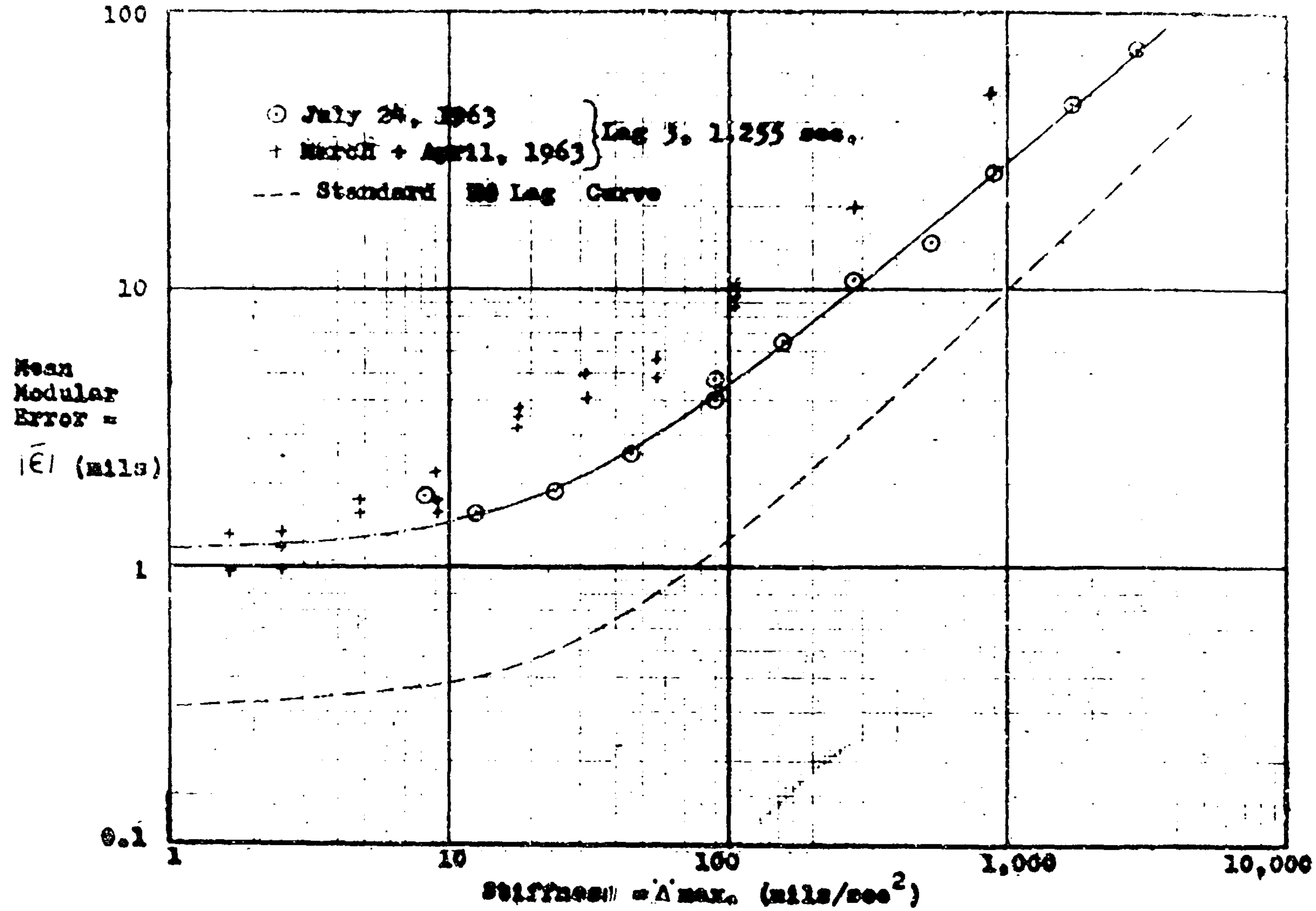


Fig. 5. Effect of Lag at High Stiffness — with Extra Training.
(Subject No. 1 - N.K. Walker)

effect of gain in future tests.

The same curve can be used as a basis for comparison even in the presence of lag, since over a moderate range of stiffness the effect of lag is to increase the errors by a fixed factor.

6. THE EFFECT OF THE FINITE WIDTH OF THE DISPLAY ZONE ON TRACKING ACCURACY

Rubric tracking is based on the ability to notice and remember a peak error, and then to reverse control when the error has been reduced to a predetermined part of the peak error.

In the case of zero lag control is reversed when th[illegible] midway between the peak and the zero mark, but with a lag of 1.[illegible] nds, control must be reversed as soon as the deflection has passed it[illegible].

It was felt that if a peak occurred near the bounda[illegible] of the display zone, the Subject would judge the peak, and the spot position, relative to the boundary of the paper and not to the zero mark, and hence might give improved performance.

Subject #22 was tested over the gain range from 1 to 10 (which he could barely control) using the normal arrangement with a display zone 6" wide (300 mils) and the error trace given in Fig. 6 (lag = 1.255 seconds.)

A mask was then inserted between the Subject and the Visicorder to cut the display zone to 2" width, and then 1.2" width (60 mils). The results showed that as the gain was increased, the mask had no effect until the mean peak error approached the half width of the mask. At this point the gain could be doubled (1 step) and sometimes quadrupled (2 steps) without increasing the error. A further increase in gain then caused loss of control. (Figs. 7 and 8) Note particularly the comparison between the results at gain [illegible].

Results with no lag showed no effect of the mask; control was lost as soon as the peak errors approached the half-width of the mask.

Hence, it can be concluded that the finite width of the display zone has no effect on results, unless the average double amplitude of the oscillations exceeds 75% of the width of the display zone. Similarly, any fixed marker displays must be dimmed with blue filters, or kept well clear of the operating region.

7. STANDARD TRACKING TASKS A & B

Since large groups of Subjects are unlikely to be tested over a wide range of stiffness and lag, it is desirable to choose particular values for future work.

Subject #22
Stiffness... variable
Lag... 1.255 seconds

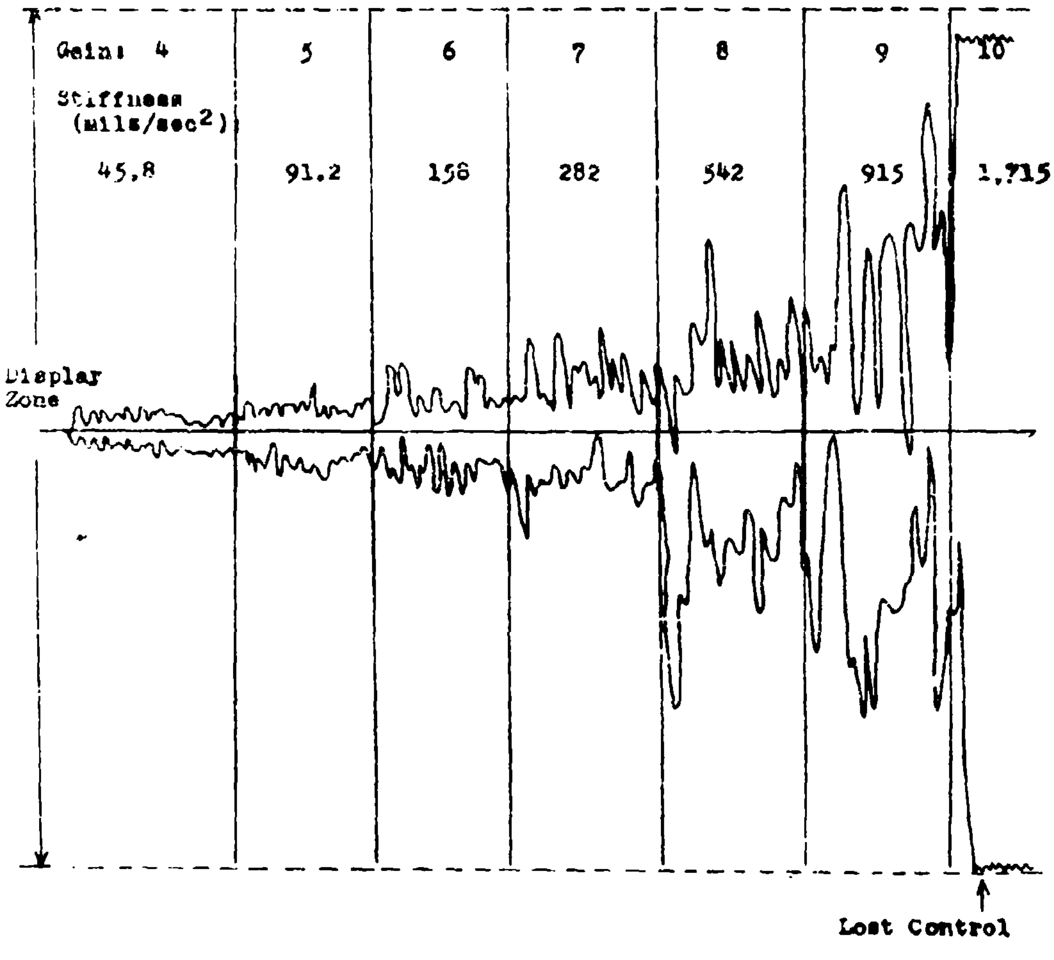


Fig. 6 Variation of Tracking Performance with Gain. Full Width Display Zone. (6")

Subject #22
Stiffness... variable
Lag... 1.255 seconds

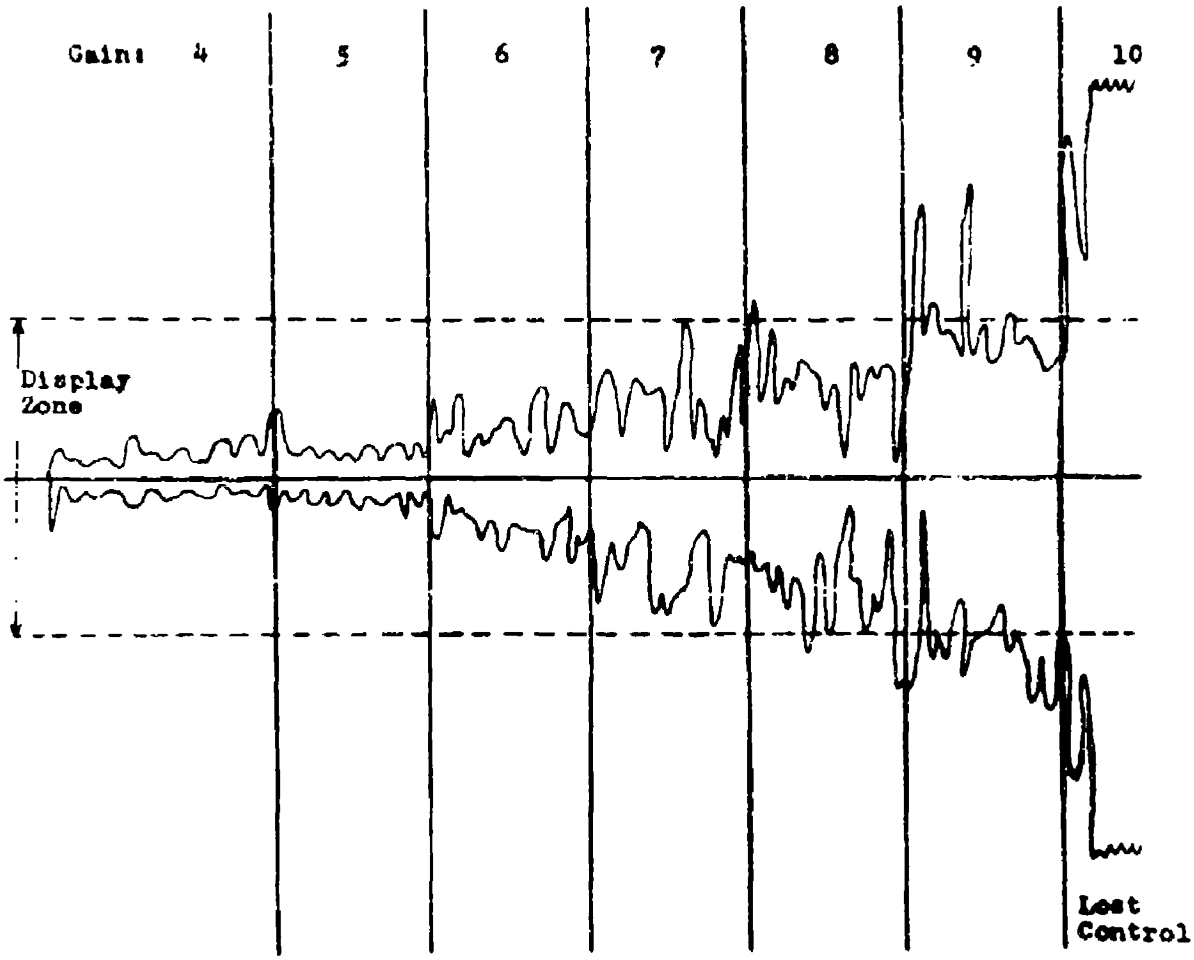


Fig. 7 Variation of Tracking Performance with Gain. Display Zone Width Reduced to 2".

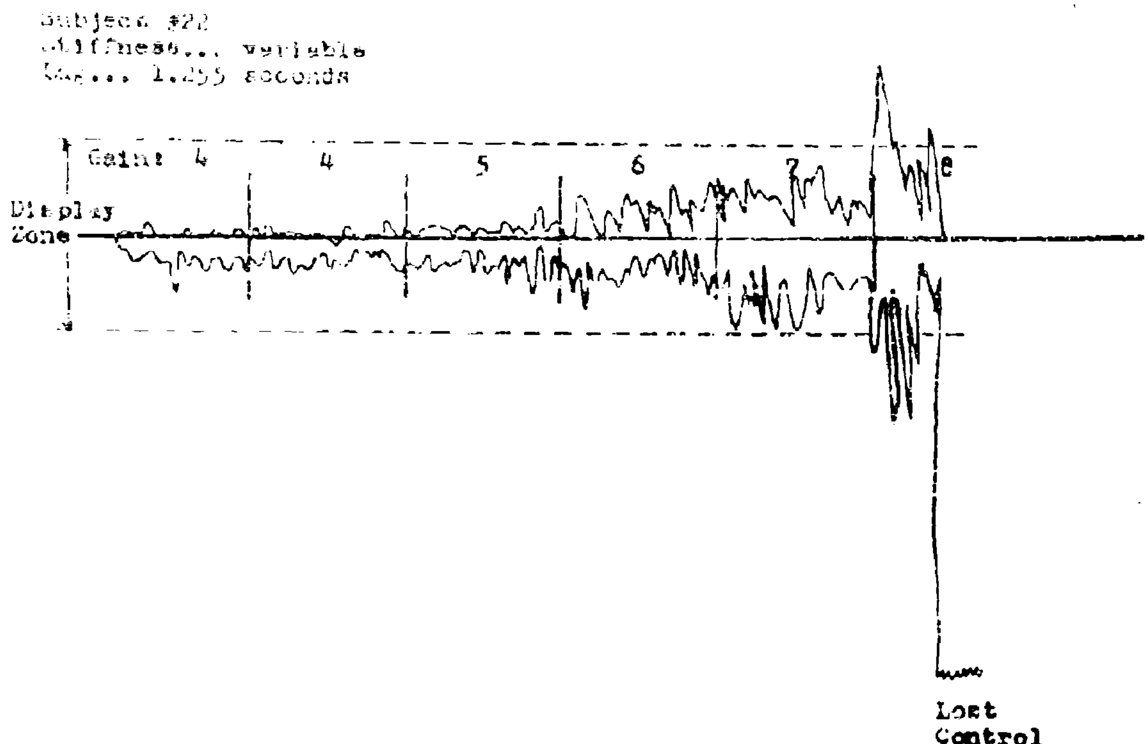


Fig. 8a Variation of Tracking Performance with Gain. Display Zone Width Reduced to 1.2°.

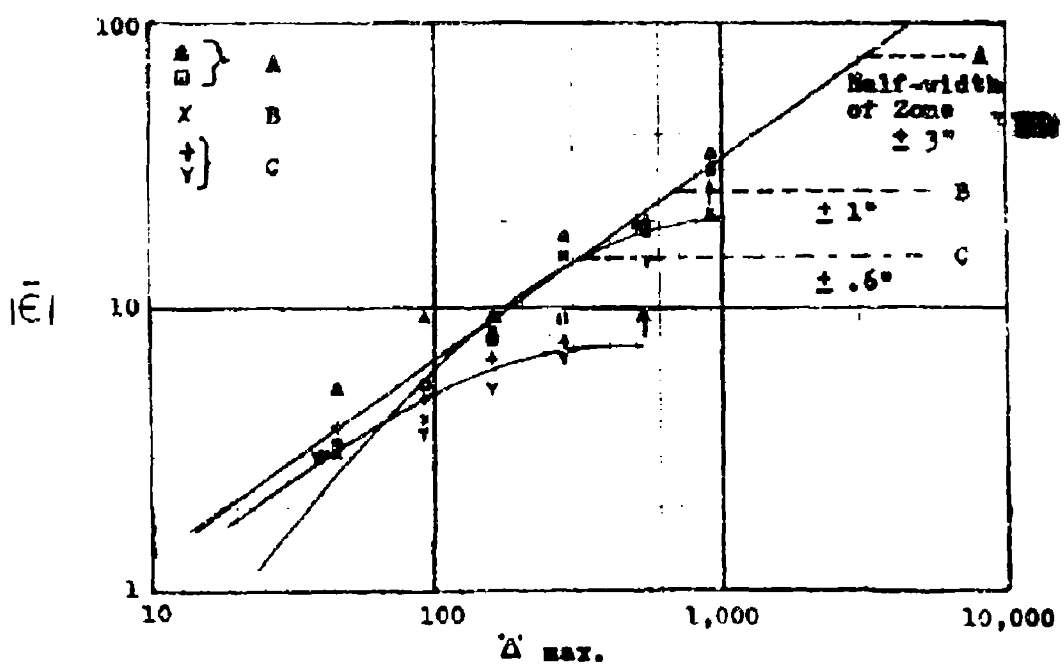


Fig. 8b The Effect of the Finite Width of the Display Zone on Tracking Accuracy.

The gain settings should be chosen to insure that the error is large enough for the Subject to see it easily, but not so large that under stress the increased oscillation amplitude (possibly a factor of 6) is comparable with the width of the display zone.

At the same time, the most difficult Tasks, i.e., with lag, should have noticeably larger amplitude oscillations.

It was decided to standardize on two values of the lag only, zero lag and 1.255 seconds. A gain setting of 6, (158 mils/sec^2) was chosen Task "A", i.e., the zero lag task, and of 5 (91.2 mils/sec^2) for Task "B" - lag = 1.255 seconds. A typical well-trained Subject can maintain a peak error amplitude of less than $\pm$ 1 space (10 mils) with Task A, and $\pm$ two spaces (20 mils) with Task B, thus permitting increases under stress by a factor of the order of five.

The gain of the error readout is, of course, changed from Task A to Task B so that the movement of the accumulated error readout spot does not intrude into the working space.

8. TRAINING TECHNIQUE

8.1 Theory of Rubric Tracking

Suppose the indicator spot is central and immediately accelerates to the left when the ZITA is turned on. Then the Subject will move the stick to the right, and the spot will slow down, come to a halt, and commence to return towards zero. Since all the trajectories are part of a uniform parabolic arc, it can easily be seen that if there is no lag at all in the system, reversing control when the spot is halfway back will cause the spot to come to a halt exactly on the zero line.

The operator may decide to reverse at the half-way point, but in practice there will be some delay in the operator's response, "t" seconds and his response will be late. The spot will then overshoot and commence to return to the zero from the opposite direction. Suppose the same rule is applied again, there will be a smaller overshoot, and in the limit the spot will oscillate across the zero mark with a fixed amplitude, the operator deciding to reverse control in each case at the halfway mark, and the actual reversal occurring exactly as the spot crosses the zero. Naturally, the time period for these small amplitude oscillations is much less than for the large ones.

It is easy to show that for such perfect Rubric tracking the amplitude of the terminal oscillation is - $\pm$ 5.82 $\Delta_{max}\ t^2$ or $|\epsilon|$ = 3.88 $\Delta_{max}\ t^2$ where "t" is the reaction lag of the operator and is about 0.1 seconds. Similarly, the period of oscillation is 13.78t.

No such simple, perfect relations exist for the lag case. The best we can do is to instruct the operator to reverse control as soon as the spot has passed the peak and leave him to improve his own judgment through practice. (Reversal exactly at the peak is always too early.)

Rubric tracking does, however, do three things well:

(a) it shows the operator how to reduce a large error immediately to a much smaller value;

(b) it shows the operator how to control for a mistake. If the operator makes a mistake, the result will be a large swing. Using the Rubric, the operator can correct this large swing at once into the "tracking" boundaries, without successive overshot. This tends to give the operator great confidence in his ability to control the device;

(c) it encourages the operator to speed up, and hence, gain accuracy.

These results lead to the conclusions that a training program must firstly give precise instructions to aid the operator acquire the "Rubric", and must then assist him to sharpen his response so that the maximum reliable speed is obtained.

These conclusions have, of course, only developed over the whole period of use of the machine and were not formalized until the actual final experiment.

8.2 Early Results of Training

The training of the original Subjects used in the first year's work was haphazard and complicated by difficulties with the equipment. However, the experimenters had evolved the following principles for training:

(i) The Subject should be given a short demonstration showing the acceleration response of the spot to stick movement, but no tracking.

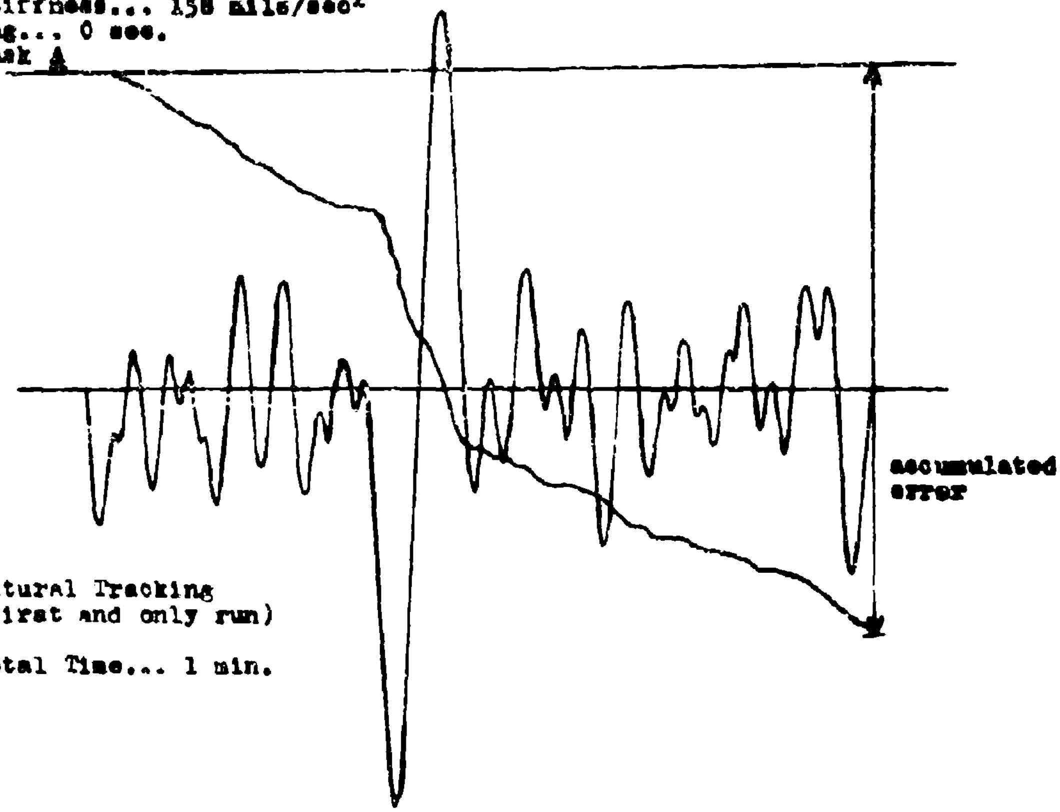
(ii) He should then be allowed one full minute tracking with no instruction on Task A ("Natural" tracking).

(iii) He should then be told the principles of "Rubric" tracking and should be shown how this enabled the Subject to correct the large errors.

(iv) The Subject should then be told to use Rubric for several successive runs and his result discussed in detail after each minute.

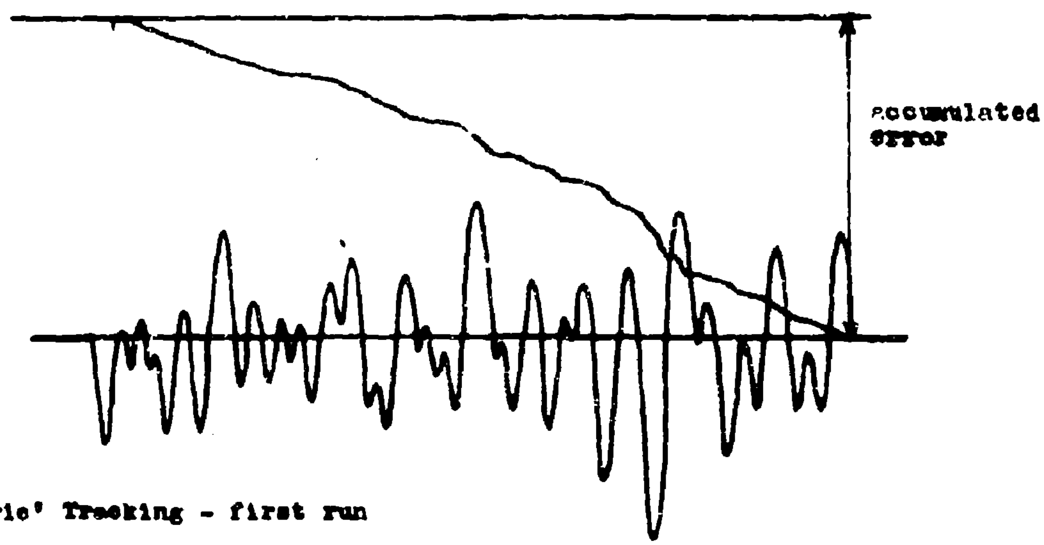
This scheme was tried formally for the first time with Subject #21 in April, 1963. His results show (Fig. 9, 10, 11) a considerable improvement when Rubric was first used, then a pause with little improvement, and then a rapid improvement in accuracy.

Subject #21
Stiffness... 158 mils/sec^2
Lag... 0 sec.
Task A



Natural Tracking
(first and only run)

Total Time... 1 min.

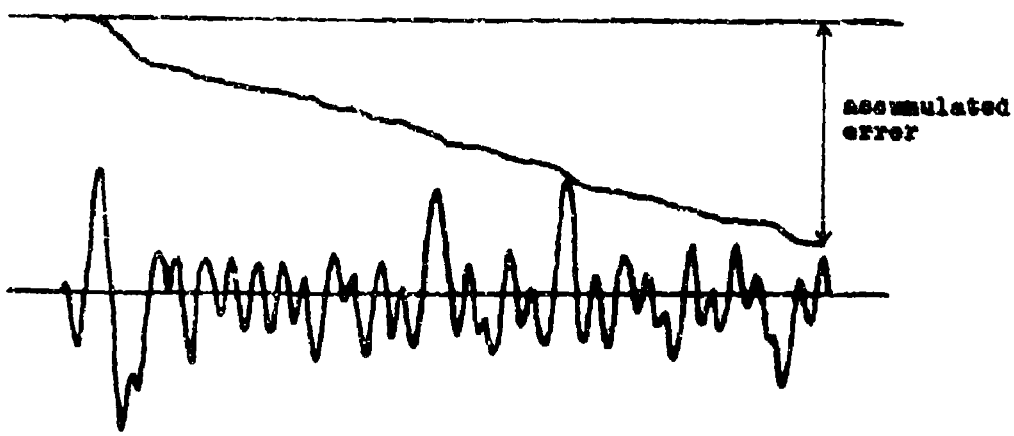


'Rubric' Tracking - first run

Total Time - 2 min.

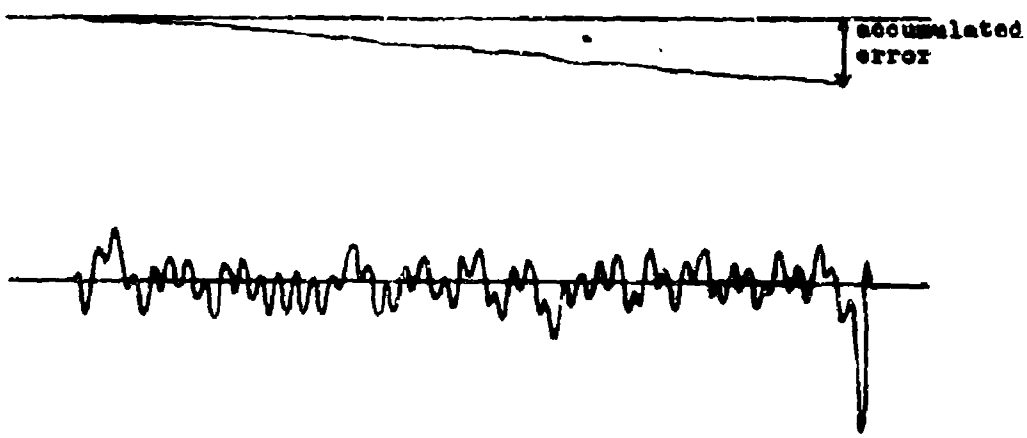
Fig. 9 The Learning Process for Subject #21 (first two runs).

Subject #21
Stiffness... 158 mils/sec^2
Lag... 0 sec.



'Rubric' Tracking - third run

Total Time - 4 min.



'Rubric' Tracking - tenth run

Total Time - 11 min.

Fig. 10 The Learning Process for Subject #21 (fourth and eleventh minutes).

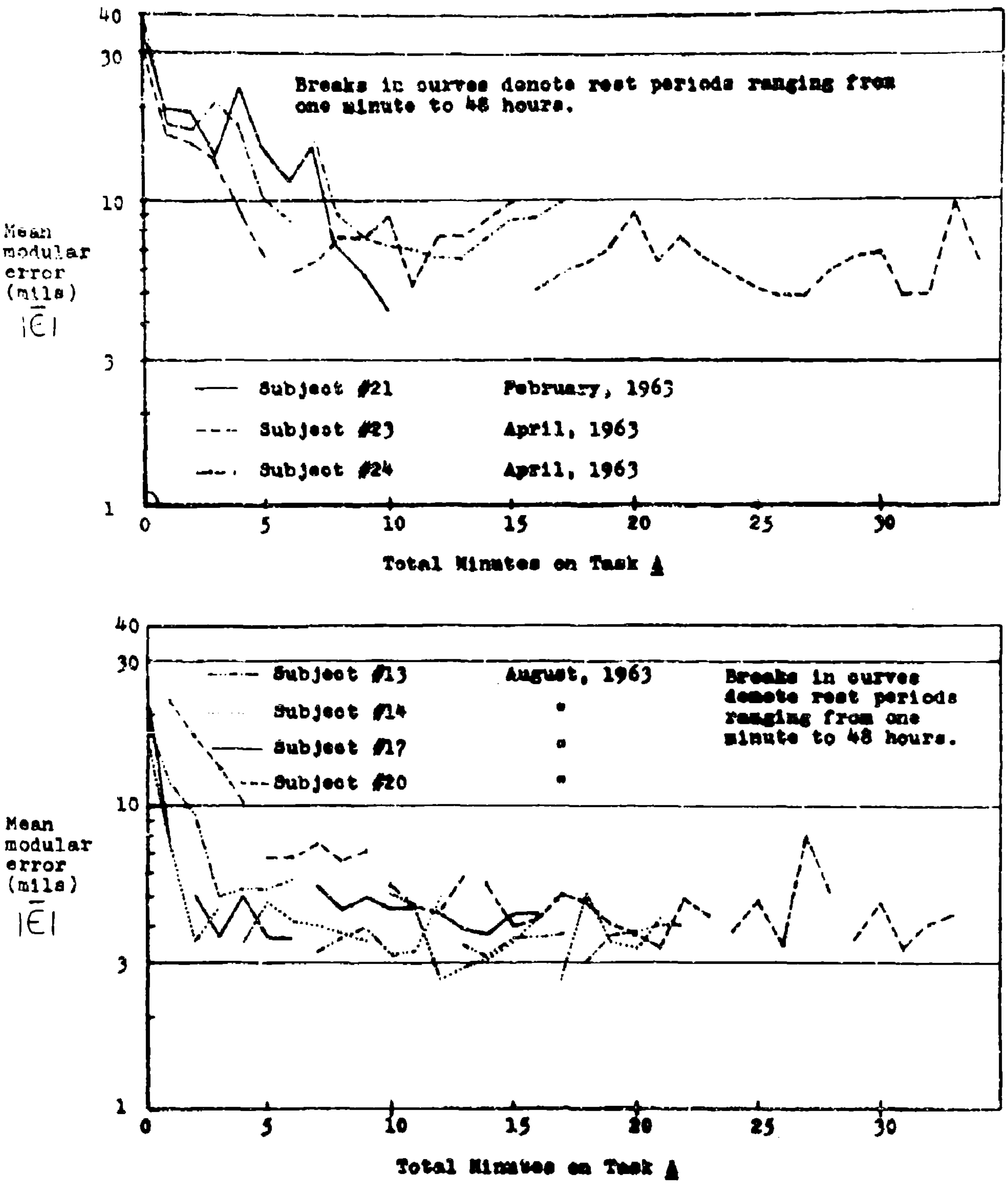


Fig. 11 The Learning Process with Two Different Training Schemes.

Shortly afterward we assisted in the training of some twenty Army Subjects, two at a time, for WRAIR, on both Tasks A and B, and decided:

(a) To give each Subject, beforehand, a target response which he should achieve or surpass

(b) To compare his Rubric results with the target response after every minute in the hope that this would eliminate the plateau shown by Subject #21.

These measures were successful, as is shown in Fig. 11 where results for Subject #21 are compared with those for Subject #24 and Subject #23 from the WRAIR group.

Several other factors emerged from the mass of these results:

(c) Subjects could be instructed in groups, and the later Subjects in a group would benefit, i. e., would need less learning time, from the experience of watching their predecessors' performance.

(d) That practice on Task A was of no value in learning Task B, once the initial rapid learning stage was passed; both Tasks required equal training time

(e) Many Subjects improved considerably after a 24-hour break, their very first run on the second day being better than any on the first day

(f) Occasional major mistakes were made by all Subjects at all times in the experiment

8.3 Training Technique for the Main Experiment

The training technique for the main experiment was designed to overcome the previous difficulties, and was reasonably successful in so doing.

Emphasis in the first four minutes of tracking was given to accuracy of timing the response, so that the Subject was encouraged to give a regular performance without mistakes. At this time, no real emphasis was given to speeding up the response to minimize the amplitude of his oscillations, in fact, the Subject was discouraged from too speedy a response if this showed any sign of causing mistakes in control.

When mastery of Rubric tracking was achieved, (normally after 2-3 minutes Rubric tracking), the gain was increased one step every ten seconds or so to the limit of the Subject's abilities. The increased stiffness tended to elicit more rapid response of the Subject. As a result, when returned to Task A, he was able to achieve a much faster response and a smaller error. In fact, Subjects commented, or were told, that the original Task now "felt much easier."

Details for each subject are discussed in Part II, but summarised results a. shown in Fig. 11 for comparison with the WRAIR Subjects.

In general, it would seem that this revised training on Task A was successful, and achieved better results than before.

Similar results were achieved with Task B. All Subjects were given as long training on B as on A and the training periods were alternated every 5-10 minutes between the Tasks.

9. THE CHARACTERISTICS OF AUDITORY SHADOWING AS A STRESSOR

9.1 Preliminary Experiments

Auditory Shadowing as a stressor was proposed by Dr. Hamilton Mowbray, Subject #12, of the Johns Hopkins University/ Applied Physics Laboratory, who has considerable experience with this Task. The Subject is asked to repeat aloud a list of words read to him from a tape through earphones, and his response is recorded. It is found that with suitable training. Subject can repeat 2 or 3 words per second with very few errors, but the Task does demand some mental concentration. (Ref. 6.)

Dr. Mowbray felt that if the Subject were performing a tracking task, his performance would be considerably degraded in the presence of Auditory Shadowing, and so would his performance at Shadowing, since the two Tasks would interfere.

A preliminary experiment was made December 1962 in which Dr. Mowbray was first trained in Rubric tracking, on gain 5 with and without lag, and was then tested with and without Auditory Shadowing at which he was very skilled. The results are given in Fig. 12 and show that the Auditory Shadowing has little effect on the tracking accuracy with no lag, but a very large effect indeed in the presence of one second lag.

9.2 The Effect of Auditory Shadowing at Various Gains

A more comprehensive experiment was made in April using Dr. Mowbray as a subject to determine whether the effect of Auditory Shadowing on tracking varied with gain.

"Rubric" tracking was used, with lag of 0, 0.105, 0.345, and 1.255

Subject #12
Stiffness... $\ddot{A}_{max}$ = 95 mils/sec^2
Stressor... Auditory Shadowing (2 words/sec)

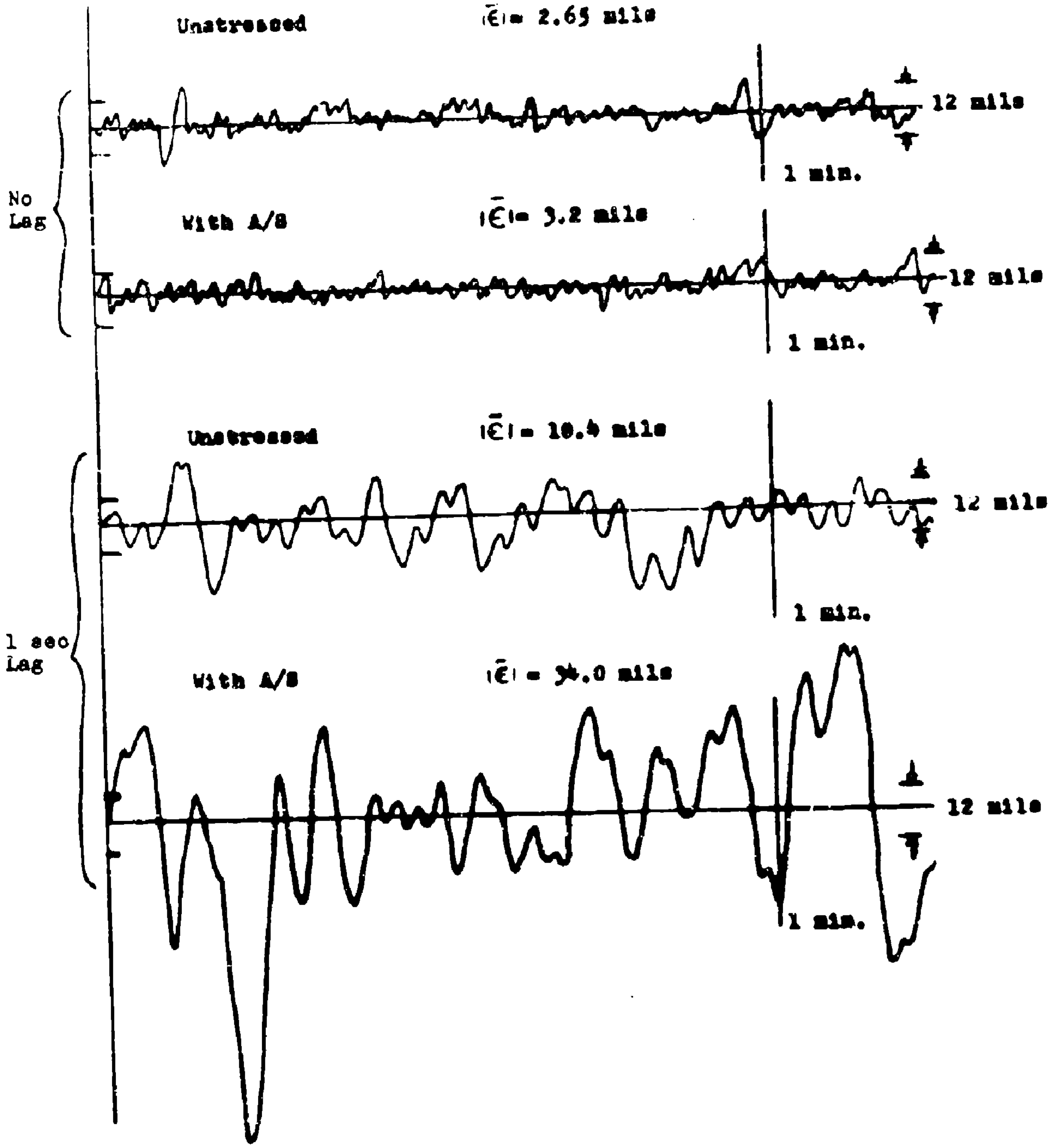


Fig. 12 Effect of Stress on "Enteric" Tracking.

seconds, and Auditory Shadowing was applied on every odd numbered gain.

The results are reported in detail in Ref. 3 and show:

(a) that the proportional effect of Auditory Shadowing on tracking accuracy increased if the lag was increased as was suggested by the preliminary experiment

(b) that the number of Shadowing errors was increased when the lag was increased

(c) that at a fixed lag setting, the effect of Auditory Shadowing was to increase the tracking errors by a constant proportion over the whole gain range

10. THE MAIN EXPERIMENT

Details of the main experiment are given in Part II of this report. The experiment was planned to confirm the effects of Auditory Shadowing on eight Subjects on Tasks A and B and a second stressor, an intermittent mild electric shock was also used for comparison. The Auditory Shadowing performance was recorded and analyzed to facilitate a future comparison with tracking, the words list was abandoned and a randomized list of the digits 1 and 2 was used instead, at the rate of two digits per second. Results are given in Part II, but show:

(a) Auditory Shadowing has a major effect on Task B for all subjects; a much less - but appreciable - effect on Task A.

(b) Subjects differ considerably in their sensitivity to Auditory Shadowing.

(c) A combined measure of performance on both Auditory Shadowing and tracking is more consistent than either individually.

(d) Mild electric shocks have little effect, except in anticipation.

11. DETAILED ANALYSIS OF THE MAIN EXPERIMENT AND COMPARISON WITH OTHER STRESS RESULTS

A detailed analysis of the Auditory Shadowing experiments is given in Part III of this report, in which the tracking task is analyzed in terms of "errors" and is thus directly comparable to the Auditory Shadowing.

The analysis shows that at different times a Subject may concentrate on tracking rather than Shadowing, or vice versa, and a "smoothing" technique is devised to correct all Subjects' results to a balanced performance. It is shown that the precise form of smoothing has little influence upon the final results.

The results of this analysis are:

(a) The increase in error of Task B in the presence of Auditory Shadowing is three times the increase in error of Task A.

(b) The increase in error of Auditory Shadowing in the presence of Task B is double the increase in the presence of Task A.

(c) The results for the effect of Auditory Shadowing on tracking are very closely in agreement with the results for the effect of combat on tracking accuracy given in Ref. 4 and 5.

FINAL REPORT

JULY, 1962 - JANUARY, 1964

USAMEDS CONTR. NO. DA-49-193-MD-2369

FURTHER WORK ON THE USE OF
TRACKING TASKS AS
INDICATORS OF STRESS

PART II
THE EFFECT OF AUDITORY SHADOWING AND ELECTRIC SHOCK ON THE TRACKING OF EIGHT COLLEGE STUDENTS

By

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Elizabeth De Socio

and

Norman K. Walker

1. INTRODUCTION

This part of the Report describes in detail a carefully designed experiment run on eight college students to investigate the effects of stress on tracking performance.

Two standard tracking tasks, A and B, were employed for each Subject, with two stressors, Auditory Shadowing and a series of intermittent electric shocks. (See Page 2)

All subjects were trained as well as possible on tracking and Shadowing, and the experimental design was counterbalanced to avoid sequence effects.

2. EQUIPMENT

2.1 The tracking task.

The tracking task was provided by the ZERO INPUT TRACKING ANALYZER, which is discussed in detail in References 1 and 2. A block diagram of the equipment is shown in Figure 1.

The Subject was seated in front of the Visicorder display at a convenient distance and attempted to hold a spot of light in a fixed 'zero' position by operating a control stick. The stick caused the spot to accelerate to the left or to the right, and as only these two extreme positions of the stick were available, the best possible performance consisted of a uniform oscillation of the spot about the zero. The displacement of the spot (ϵ) in milliradians as seen by the Subject, could be averaged over a time interval as the mean modular error ($|\bar{\epsilon}|$), and was obtained from the ZITA records.

2.2 Description of equipment.

The ZITA equipment and the Visicorder are shown in Figure 2. To reduce distractions which might interfere with the tracking task and to ensure that all Subjects were operating at the same distance from the Visicorder display, a hood with rubber eyepieces was interposed between the Subject's head and the Visicorder. This hood is considered desirable as standard equipment.

2.3 The Stressors.

(a) Electric Shock

Electric shock as a stressor was employed in the following manner. An output from ZITA was used with a voltage adjustable through a range from 0 to 100 volts, DC, connected to a 40 micro farad capacitor which was thus normally charged.

A switch held by the E, depressed at the appropriate time, first disconnected the capacitor from the DC power supply and then connected it to the Subject through a 10,000 ohm resistor -- thus administering a pulse shock.

Prior to the actual shock condition the pain threshold for each S was determined. This was done by increasing the shock voltage in successive increments from zero. During the experiment, shock was administered appreciably above the threshold in order to be sure that the S's experienced pain, or at least discomfort.

Two strips of brass were employed to deliver the shock. They were taped to the middle finger of the left hand (all S's were right handed so the left hand was not otherwise used during the tracking task.) The area under the brass electrodes was coated with Redox electrode paste in order to reduce both resistance of the skin and the variability due to perspiration and polarization of the electrodes. Then, to make sure the shock would not travel up the arm, some Redox paste was applied and a length of wire was wound about the S's left wrist.

(b) Auditory Shadowing

Previous research using this stressor showed that the repetition aloud of a list of words fed to the Subject through earphones while he was tracking did result in a decrement in tracking performance. This result is discussed in detail in our previous interim Report, Reference 3.

For the present experiment some changes were introduced. Instead of the word lists, we used lists of digits 'one' and 'two' in a random order heard at the rate of 2 digits per second. After every 32nd digit another different single digit was heard to maintain the Subject's interest and to key the results for subsequent analysis. The Subject heard the lists via earphones from a tape recorder and was required to repeat them while he performed the tracking task. The Subject's verbal performance was analysed by recording his output and comparing it with the pre-recorded lists. A typical digit list is given in Table 1. Auditory Shadowing can perhaps be classified as a "distraction" type of stressor.

Both Auditory Shadowing and electric shock provide a form of "task-induced" stress (Reference 7, 1952), if we define "task-induced" as a manipulation of the experimental environment in such a way as to produce demands (upon S's operating in that environment) which are excessive when compared with those of the regular (no stress) condition.

We assumed that the application of shock and A/S would bring about differing degrees of behavioral disruption, possibly through physiological and/or psychological processes. It seemed quite possible that S's tracking behavior would be less efficient during A/S than during electric shock.

Table II also shows that for each stressor, a Pre-Stress, Stress and Post-Stress measure was obtained. This technique is in accordance with an experimental procedure developed by Reference 8, (1945). "The control or pre-stress period allows one to obtain a basal measure of behavior prior to the introduction of stress which can then serve as a frame of reference for evaluating the change in performance brought about by stress. The post-stress period permits observations of such important characteristics as the rate of recovery (and amount of recovery as well as variability of performance). Reference 9, (1952), p. 8."

The Subjects were trained to a criterion level on Auditory Shadowing. However, no Subjects received electric shock prior to the actual experiment. We felt that it was a very mild shock, and that previous reception of it would cause Subjects to become accustomed to it. It would then be an ineffective stressor and would not cause any degradation in tracking performance.

During the experiment each S tracked for 30 minutes. Therefore, on each of the days the Subject ran 10 trials for Pre-Stress, 10 trials for Stress and 10 trials for a Post-Stress measure. In addition, one minute practice trials on Tasks A and B were allowed at the beginning of each day. We also interpolated two one-minute rest periods between the Pre-Stress, Stress and Post-Stress sessions. This procedure was arranged in order to avoid any fatigue or cramp in the fingers which may have built up and could otherwise act as an uncontrolled variable giving a performance decrement.

3. EXPERIMENTAL DESIGN

3.1 Method and Procedure

This experiment was conducted at WRAIR, Forest Glen, Md., during August and September of 1963. Our Subjects were eight male college students ranging in age from 21 to 29 years. The S s received essentially the same amount of training over a period of three days. They trained a minimum of 20 minutes each on each of three days, but additional training was given some Subjects to ensure that they reached asymptotic performance as described in the next section. Then each S returned for the two days of the actual experiment, which ran for approximately one hour on each day. To control for diurnal variation, each Subject was run at the same time on both experimental days.

The learning results are plotted for each Subject in Tables IIIa through Xd. It is seen that all S s were trained to a fairly asymptotic level of performance prior to their actual running under stress conditions. After this performance was obtained, the Subjects were run according to a counterbalanced design (employed to control for sequence effects) shown in Table II.

3.2 The Design.

Prior to the experiment the S's were divided into two groups of equal performance (using as a measure the $|\epsilon|$ values taken from their learning performances). Group I ran from Task A (Gain 6, Lag 0) to Task B (Gain 5, Lag 3) when the shock stressor was employed and from Task B to A with the Auditory Shadowing. Group II ran from B to A with the shock (Sh), and from A to B with the Auditory Shadowing (A/S). This design is shown in Table II.

Group I received shock first (Table II). On Task A, it was delivered at 30 seconds and 50 seconds of trial 1, at 15 seconds and 45 seconds of trial 4 and at 20 seconds and 45 seconds of trial 5 With Task B it was delivered at 20 seconds and 35 seconds of trial 1, at 25 seconds and 50 seconds of trial 3, and at 35 seconds and 40 seconds for trial 4.

For each Task, shock was administered on three of the five trials.

Group II received the Auditory Shadowing first. They heard the digit lists on the same trials that Group I received the shock, and the tapes were arranged so that Shadowing began just after the beginning of the selected trial, and terminated just before the end of the trial. Hence Shadowing was actually applied only for 50 seconds out of each one minute run, and for only 3 runs out of 5 in the series.

On the first day of training the initial instructions were explained to the group as a whole in a semi-extemporaneous manner. A fairly informal atmosphere was developed during these first three days. However, to control for differences in verbal presentation on the experimental days, all Subjects were read a standard set of instructions.

4. MOTIVATION

We have attempted to produce an optimal level of accuracy, i.e., minimal error, for each Subject. Investigators never fail to emphasize the importance of motivation in these experiments. In view of the controversy over the meaning of "motivation" and the necessity of using the term, we have developed a usage peculiar to this study. It has been found in preliminary studies that high proficiency in tracking can be brought about by appropriate incentives, both monetary and social. The presence or availability of such incentive conditions is what is meant by "motivation" here. Holding such motivation constant was considered desirable. The disruption of the response by stressors, therefore, was expected to threaten S's anticipation of such rewards. We are confident that our stressors (A/S and shock) were of such a nature that they could interfere with the Subject's performance.

The following incentive conditions were employed. The Subjects were informed as to the importance of this type of experiment to the guided missile program; they were given knowledge of results, praise and reproof, intra-individual and inter-group competition; and the experimenters continually encouraged the S's to improve their performance. We clearly explained to the Subjects that those who improved during the experiment and the person with the "over-all" superior performance would receive cash bonuses above the hourly wage paid for their services, which in itself we feel influenced performance.

5. RESULTS

5.1 Learning.

(a) Tracking - First Session

A group of six Subjects (Nos. 15, 16, 17, 18, 19, and 20) was trained on August 26th as a group, and all members of the group were permitted to observe each other's performance during the learning period.

The first subject, No. 17, (Figure 13) was given no training at all in tracking except for a brief demonstration of the response of the display. Figure 14 shows that he scored 21 mils error with Task A. Some two or three minutes were then spent in demonstrating the principles of "Rubric" tracking, with intermittent short periods of practice by No. 17. At the end of this time, S 17 made a single run and scored 7.8 mils error. We believe from previous experience that subsequent practice would improve this performance by a factor of 2 or 3 to an asymptotic value and therefore a start was made to introduce the group to Task B.

It was explained to S 17 that Task B included a lag of one second and that his check commands should now be given much earlier. As expected, the initial result here was appreciably worse than for Task A. After five successive runs, the error readout became much the same. In fact, the actual error was 9.2 mils (Figure 15).

The next Subject, No. 20, (Figure 16) took over and his first result with Task A was comparable to that of S 17, 22 mils error. (See Figure 17) No instruction was given and in 4 successive rune (one minute each) his error went down to 10 mils.

Subject No. 20 then attempted Task B and did very well for the first two minutes. He then became confused for 4 minutes. His final two runs on B averaged better than 12 mils. This was considered satisfactory as a breakoff point for fear of fatiguing the Subject (Figure 18).

The next Subject, No. 19 (Figure 19) had obviously profited from watching the two previous Subjects learn. His initial error was 6.1 mils. He reached a maximum of 9 mils on his third run, then fell to 7.7 on the 4th run. This was considered most satisfactory, so he attempted Task B. He scored an average of better than 13 mils in 4 runs varying from 9.3 to 17 mils.

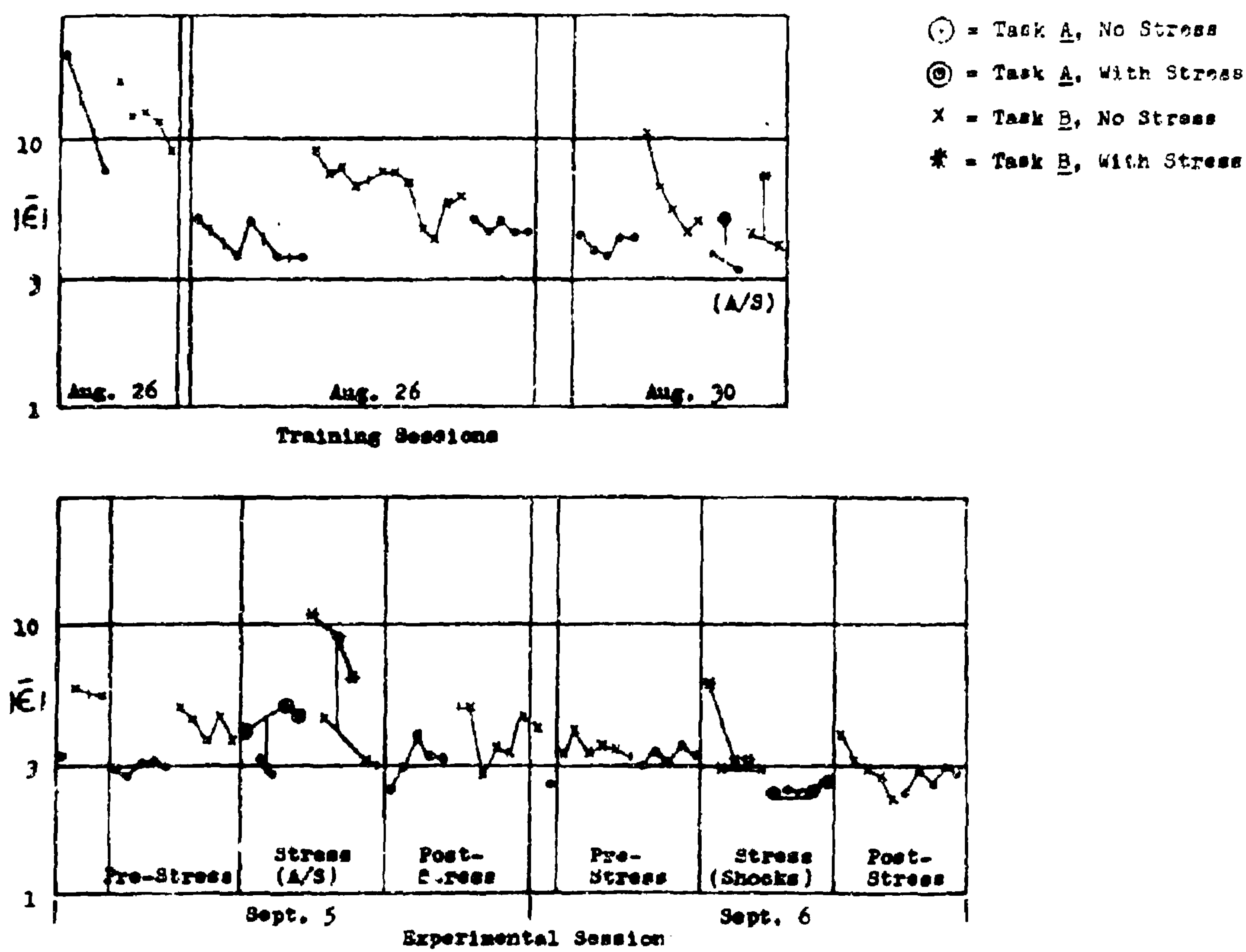
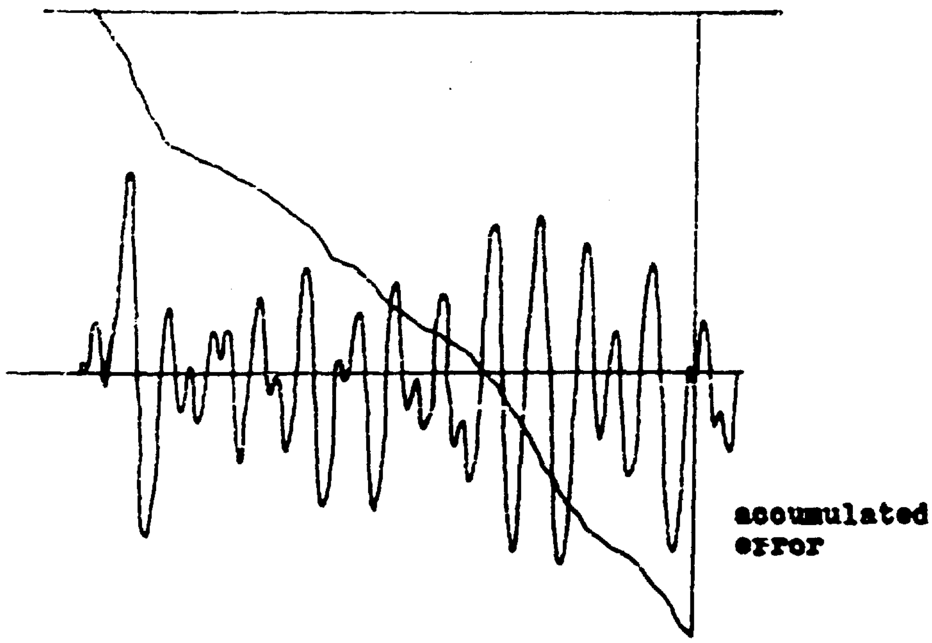


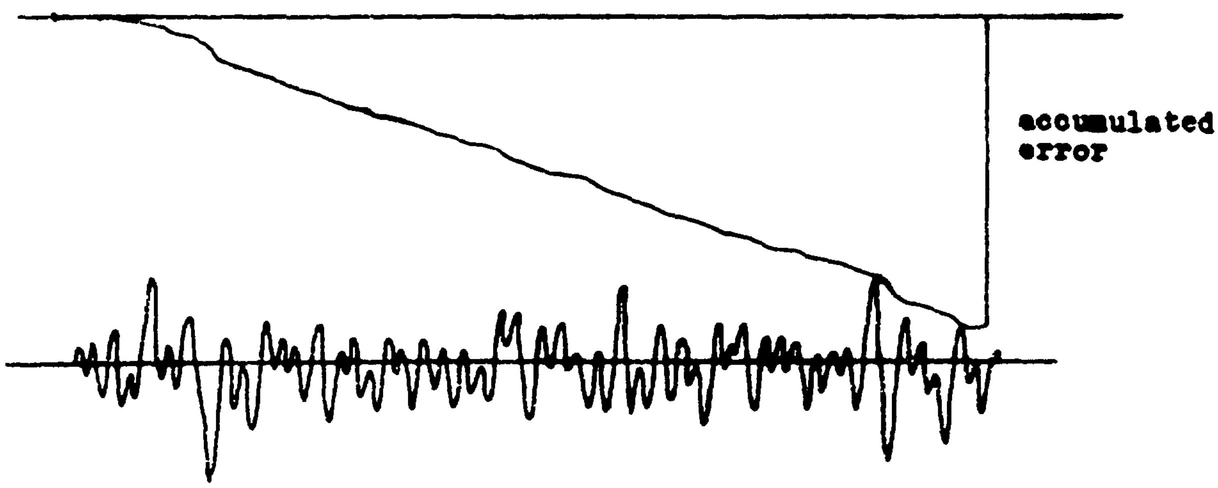
Fig. 13 Over-All Performance of Subject #17.

Subject #17
Stiffness... 158 mils/sec^2
Lag... 0 sec
Task A



Natural Tracking
(first and only run)

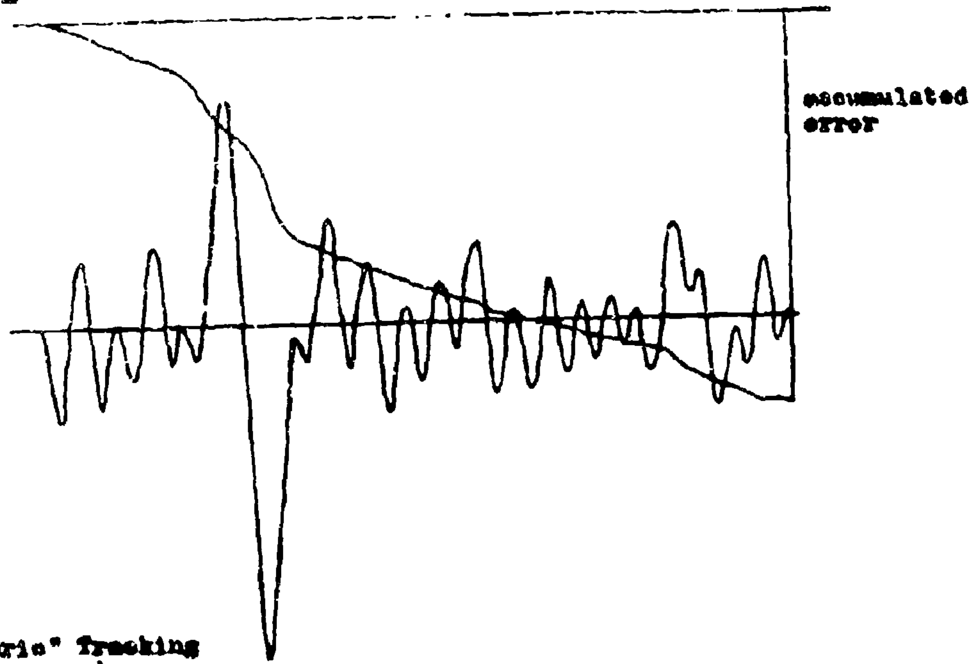
Total Time - one minute



"Rubria" Tracking
(second run)
Total Time - three minutes

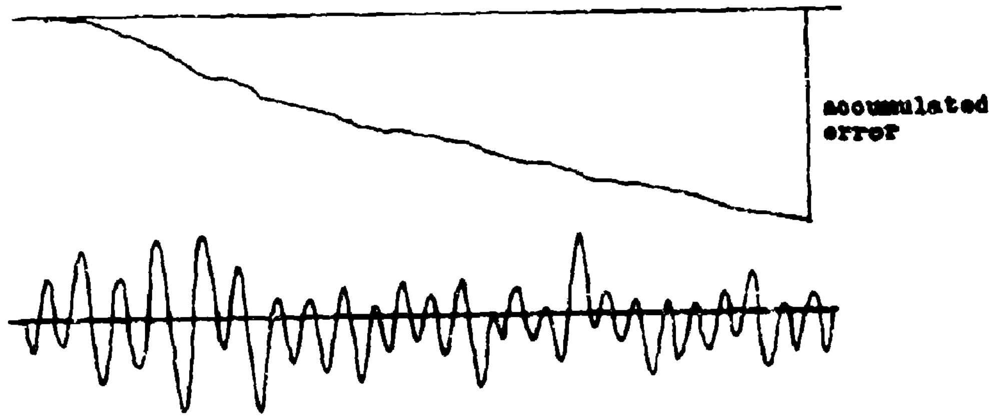
Fig. 14 The Learning Process for Subject #17 on Task A.

Subject #17
Stiffness... 91.2 mile/sec^2
Lag... 1.255 sec
Task B



"Rubric" Tracking
(first run)

Total Time - one minute



"Rubric" Tracking
(fifth run)

Total Time - five minutes

Fig. 15 The Learning Process for Subject #17 on Task B.

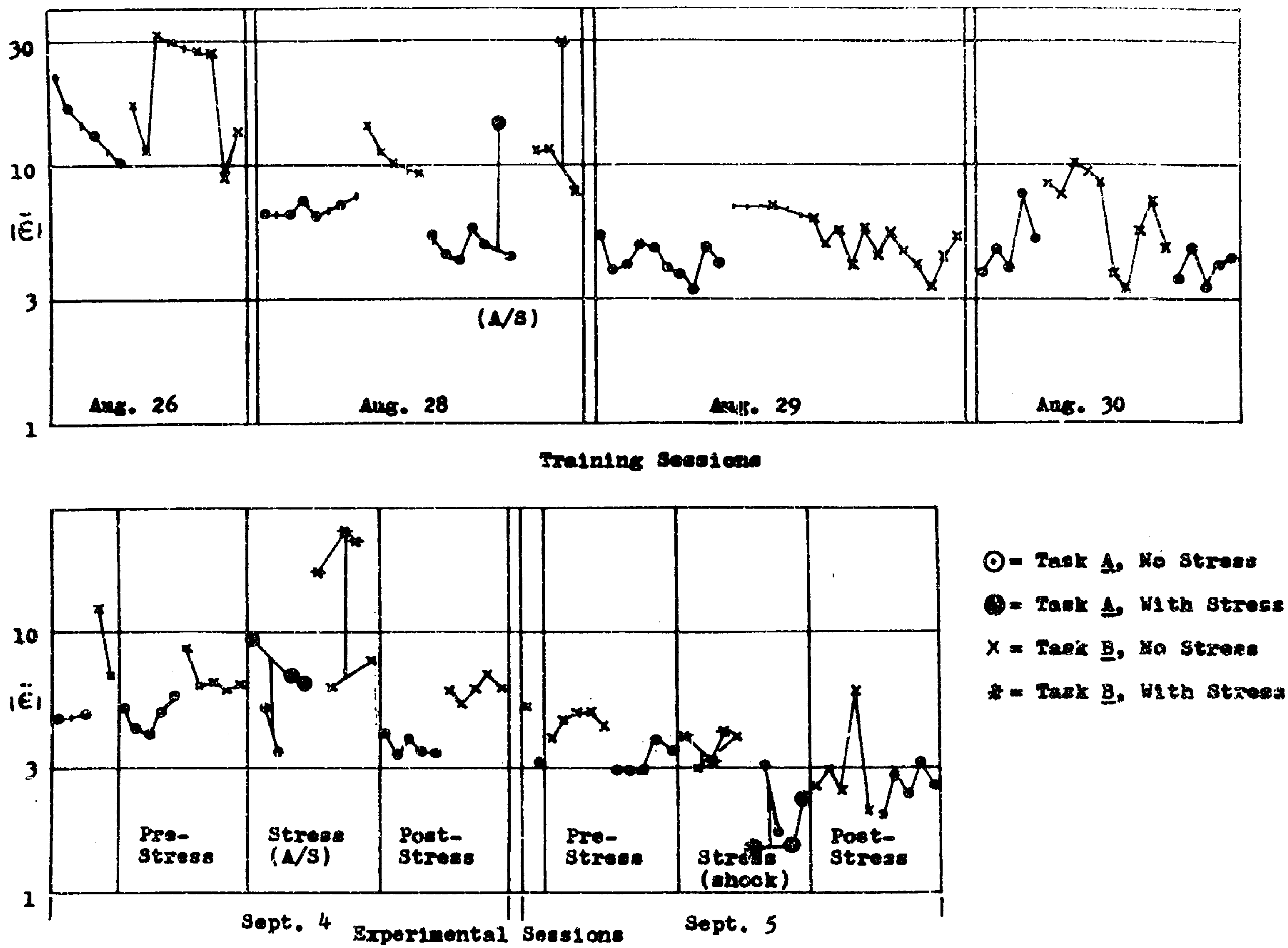
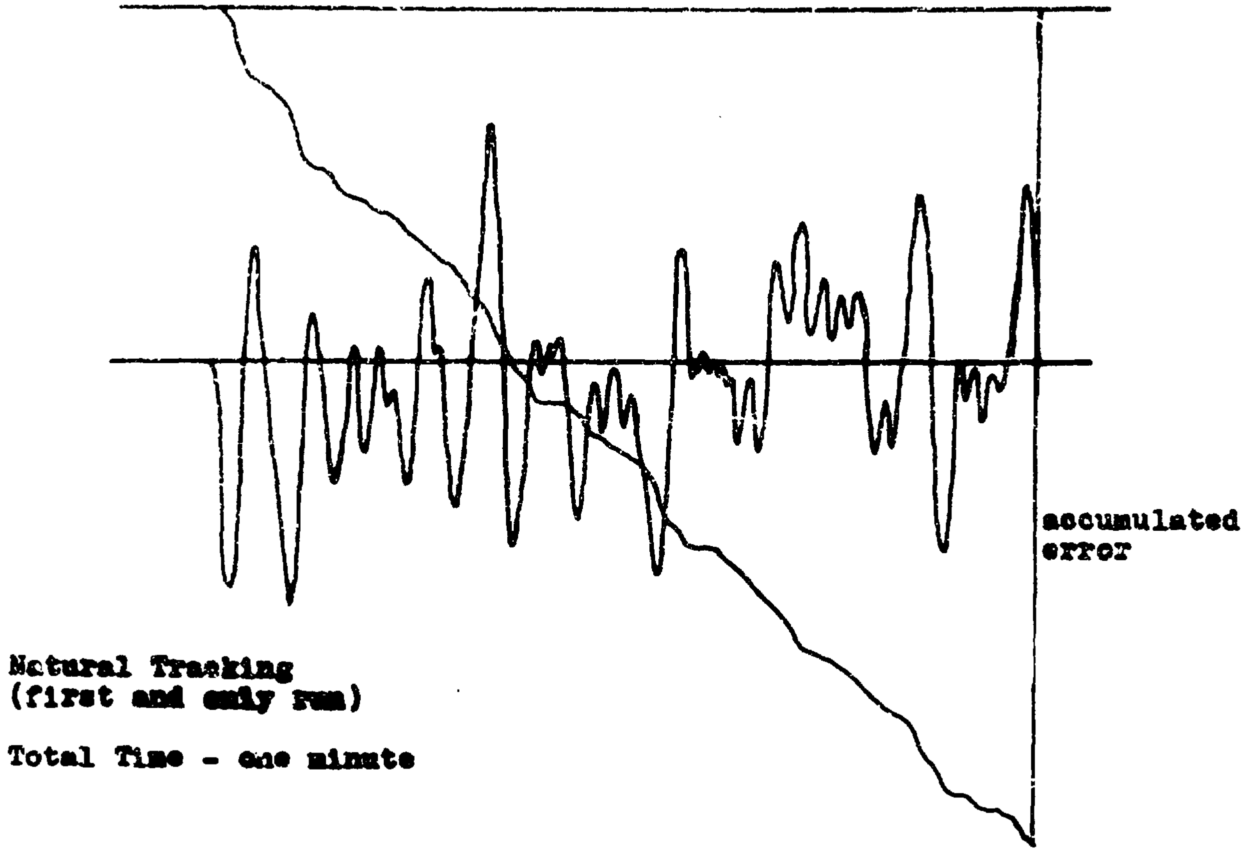


Fig. 16 Over-All Performance of Subject #20.

Subject #20
Stiffness... 158 mils/sec^2
Lag... 0 sec
Task A



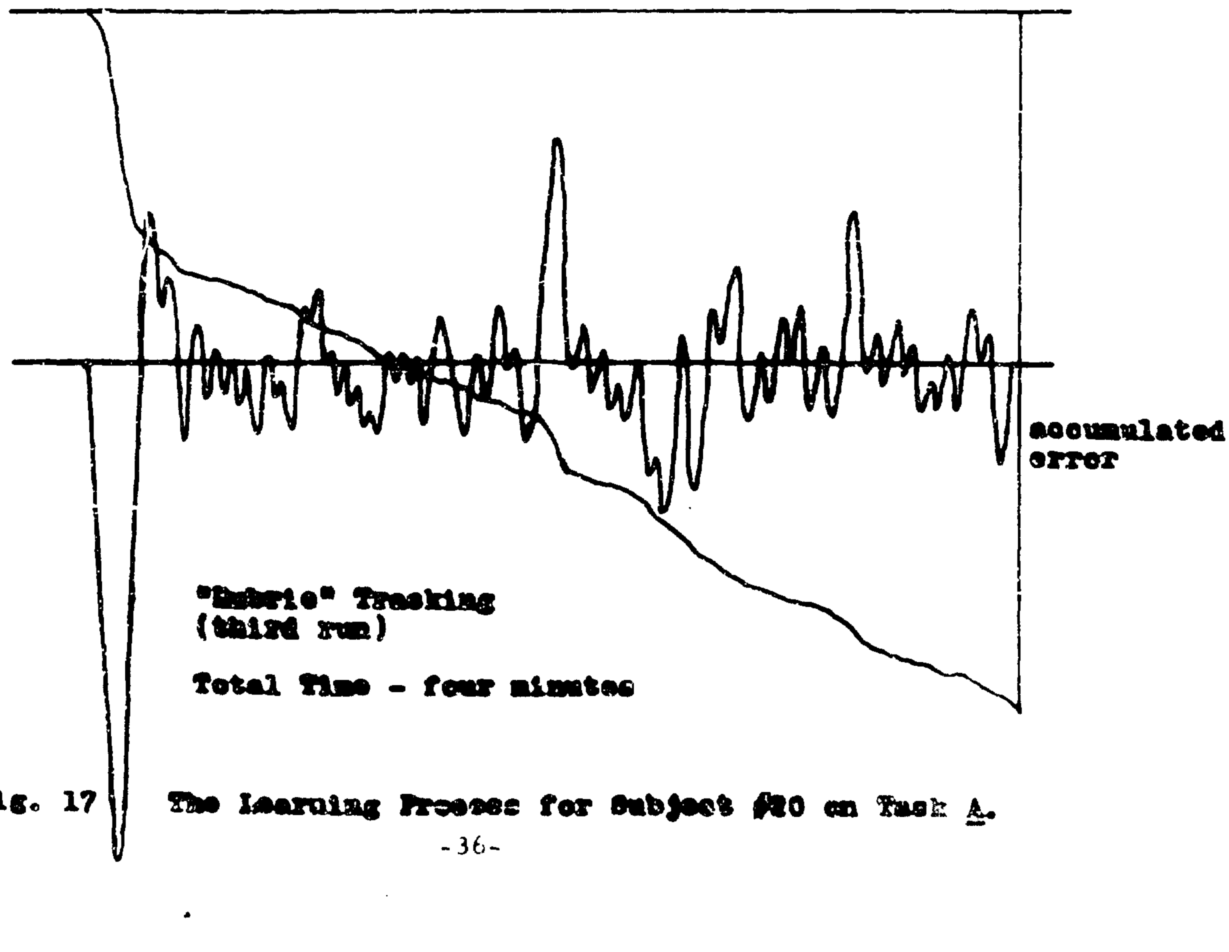
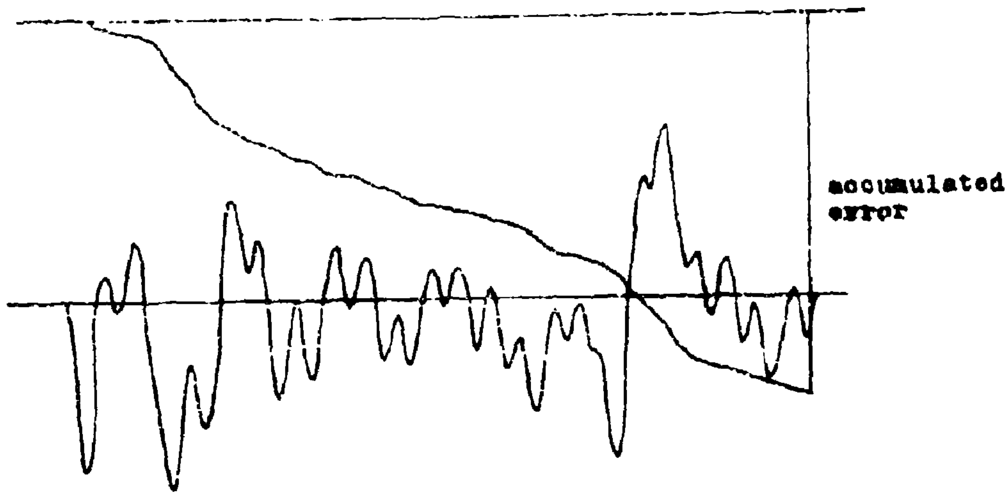


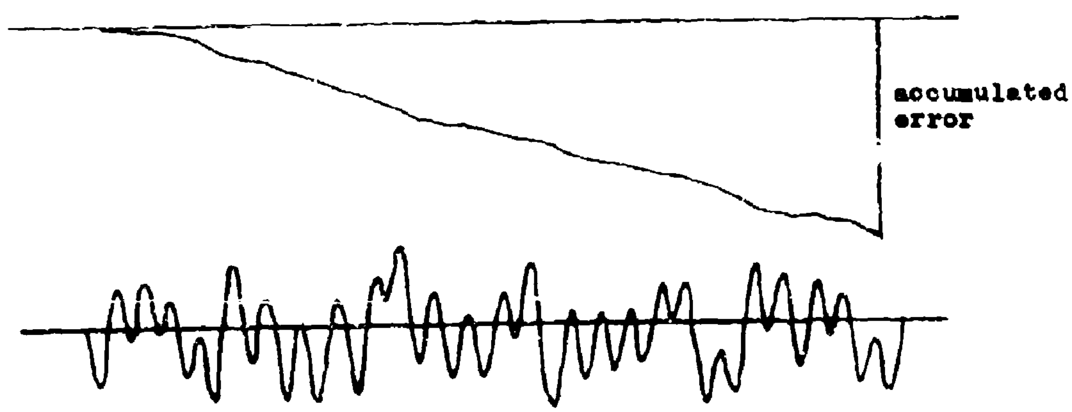
Fig. 17 The Learning Process for Subject #20 on Task A.

Subject #20
Stiffness... 91.2 mils/sec^2
Lag... 1.255 sec
Task B



"Rubric" Tracking
(First run)

Total Time - one minute



"Rubric" Tracking
(seventh run)

Total Time - seven minutes

Fig. 18 The Learning Process for Subject #20 on Task B.

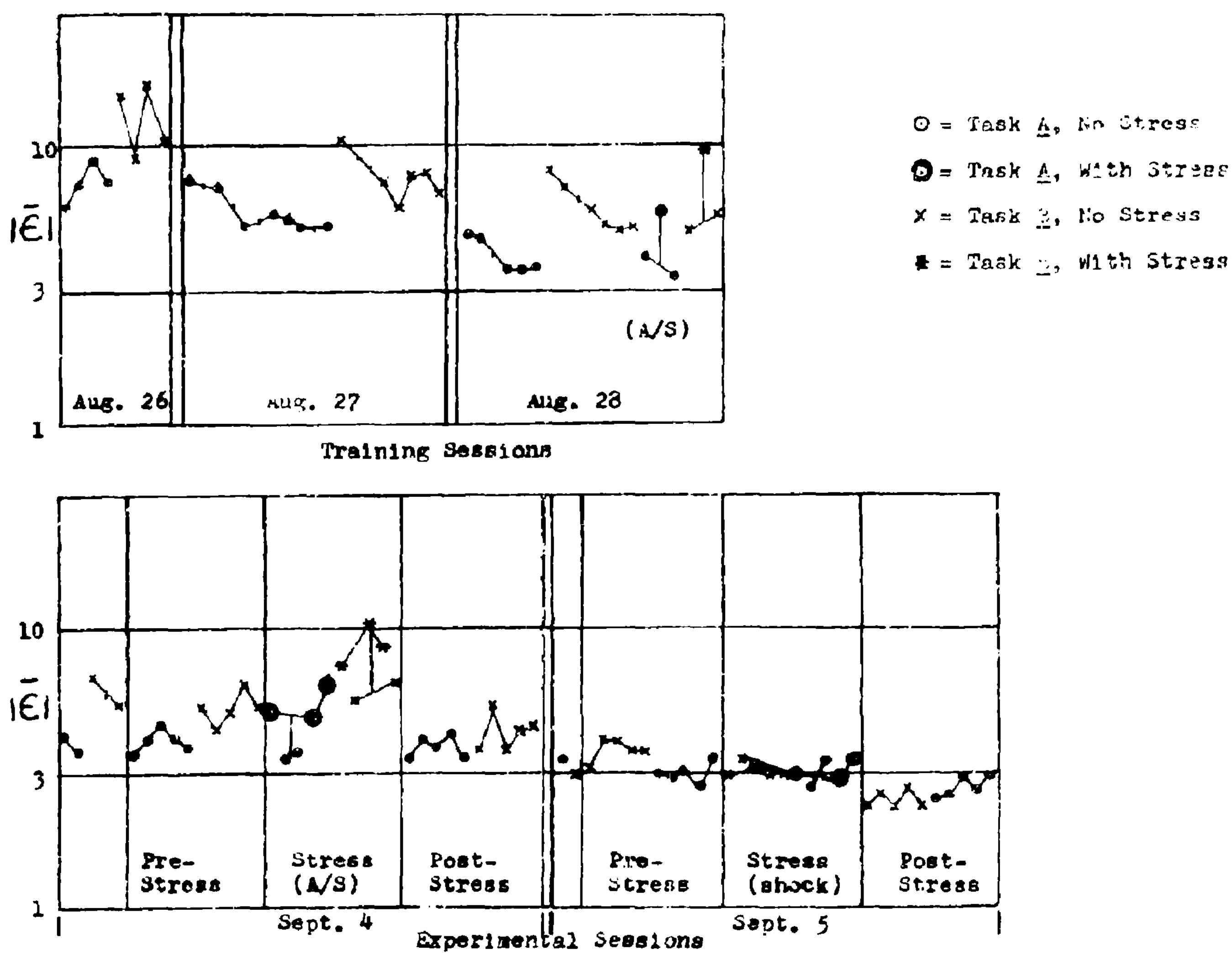


Fig. 19 Over-All Performance of Subject #19.

Subject No. 18 (Figure 20) gave even better results. His error decreased from 6.5 to 5.6 in three runs with Task A. On Task B his error decreased from the initial value of just over 11 mils to 5.1 mils.

The next Subject, No. 16 (Figure 21), had evidently not profited much from watching the others. His initial error of nearly 17 mils on Task A tended to increase through a complete series of 7 runs to 20 mils error.

As there seemed to be no hope of this Subject's improving on this first day, no attempt was made on Task B.

The final Subject, No. 15 (Figure 22), attempted Task A and scored an extremely good result of 6 mils. The next two attempts were 4.5 mils and 5.3 mils. It was obvious that he had grasped the principles of "Rubric" tracking from watching the others. Finally Subject No. 15 attempted Task B and his initial error of 13 mils improved somewhat to an average of better than 10 mils in 4 runs.

Subject No. 13 (Figure 23) was trained on August 27th. He had not been able to attend the pervious day with the group, and therefore his initial error was quite large at 18 mils. He was then instructed verbally in "Rubric" tracking and improved to 12 mils. This was followed by a short demonstration with considerable variation of gain to speed up his response -- lasting in all perhaps two minutes.

His third attempt was considerably better at 9.3 mils, and then after one more short demonstration session, a continuous run was made for two minutes giving readings of 5.05 and 5.3 mils. These were followed by a further one minute demonstration and a one minute practice with gain variation. Two more runs followed which were slightly worse with 5.3 mils and 5.7 mils. It was considered that this was a satisfactory level and that further practice would lead to fatigue. The Subject now attempted Task B and his initial error of 38.6 mils was very large as expected. This was followed by one minute of practice and demonstration. Then 2 runs and a further one minute instruction and one more run. The last two runs were slightly more than 10 mils and this was considered acceptable.

Our final Subject, No. 14 (Figure 24) was trained on the next day, August 28th, also individually. As expected the first attempt gave a large error of 19.2 mils. This was followed with 2 minutes of practice and demonstration of "Rubric" tracking technique. Then 2 successive runs gave errors of 7.1 mils and 3.55 mils. After one further minute of instruction, including a gain change, the error increased slightly to 4.7 mils. This was considered satisfactory so the Subject was introduced to Task B and scored 14.7 mils at the first attempt. Subsequent practice and instruction reduced this to 9.3 mils on the fourth run which was considered acceptable as the end of the first learning session.

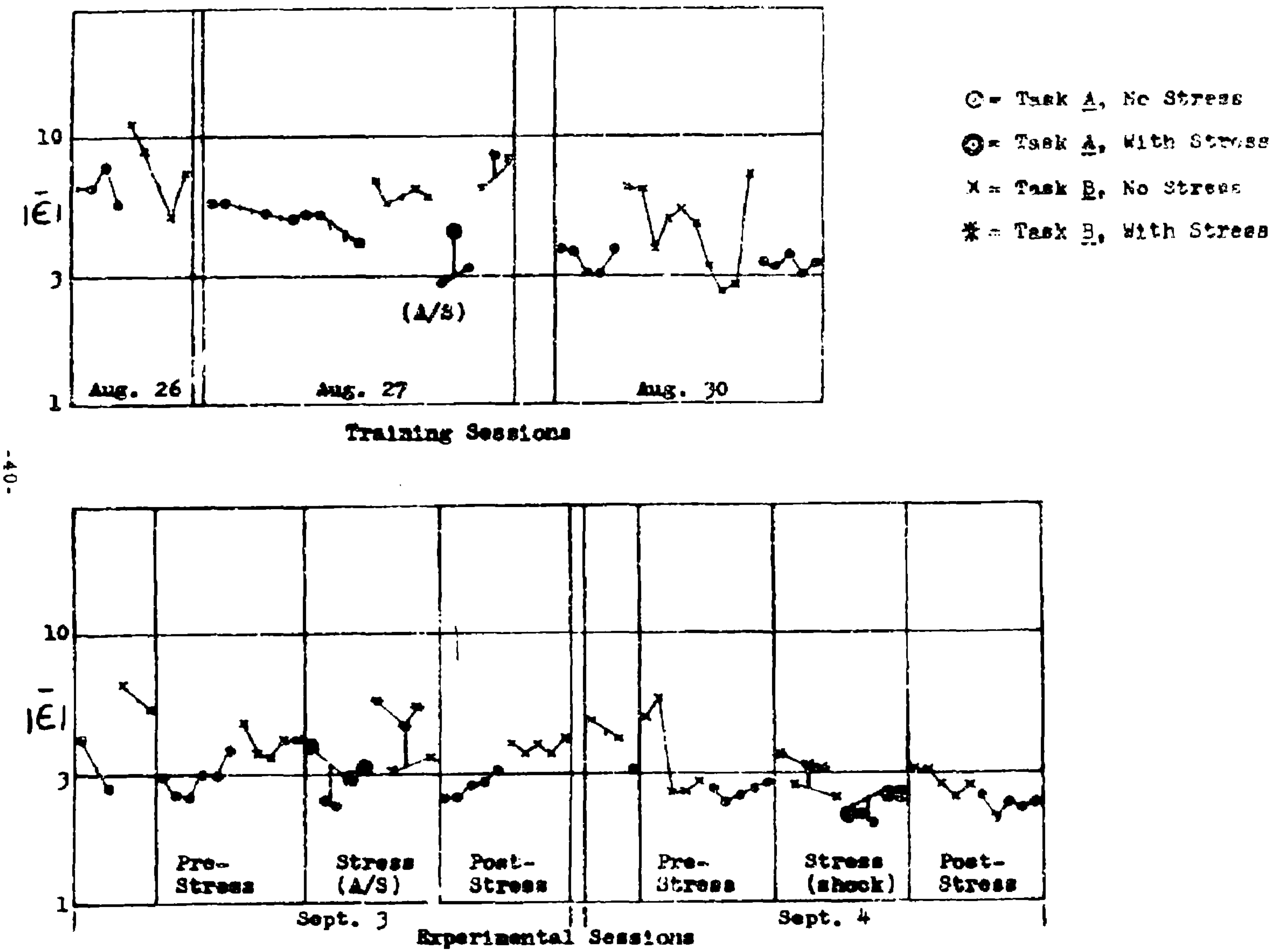


Fig. 20 Over-All Performance of Subject #18.

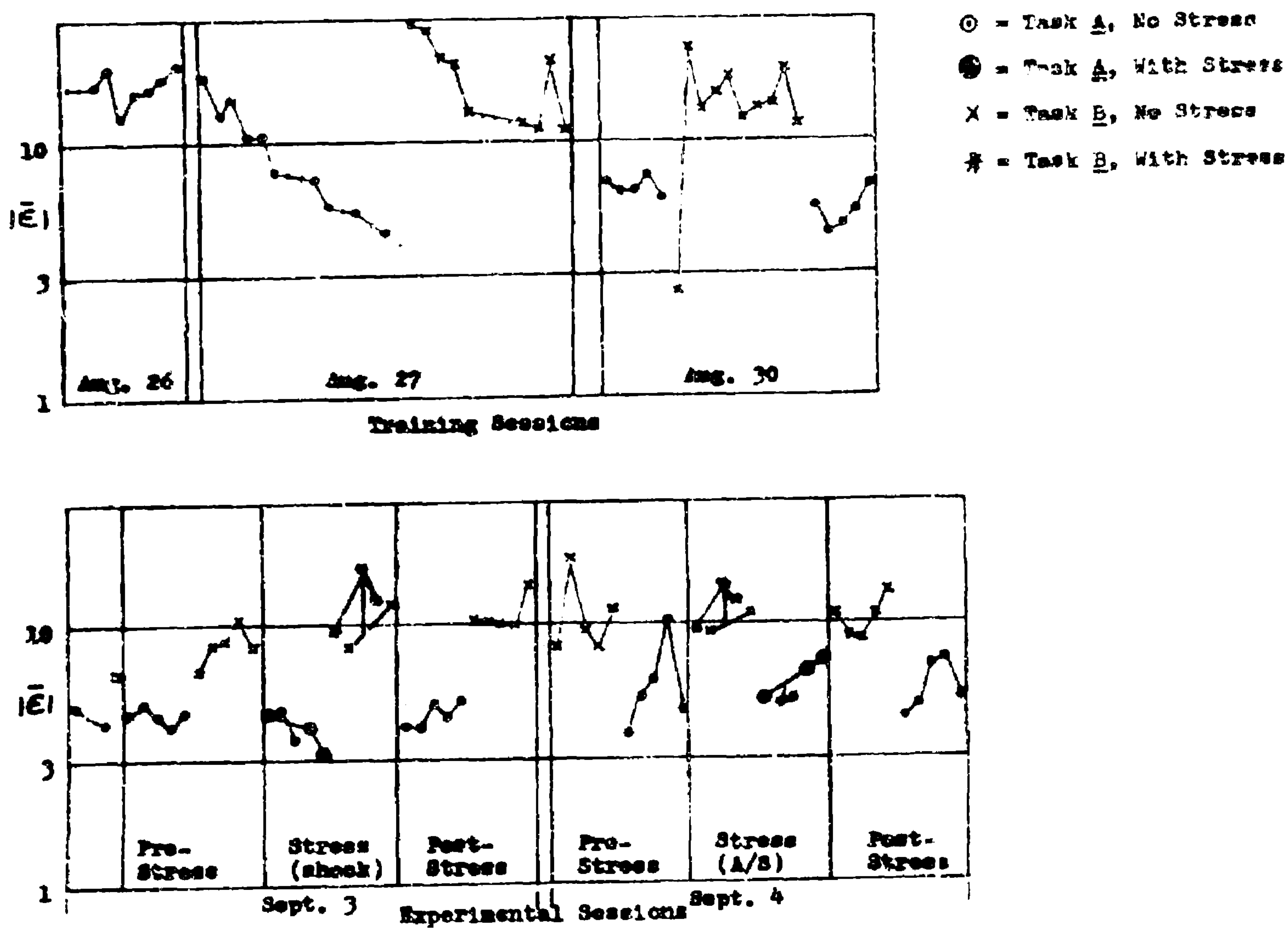


Fig. 21 Over-All Performance of Subject #16.

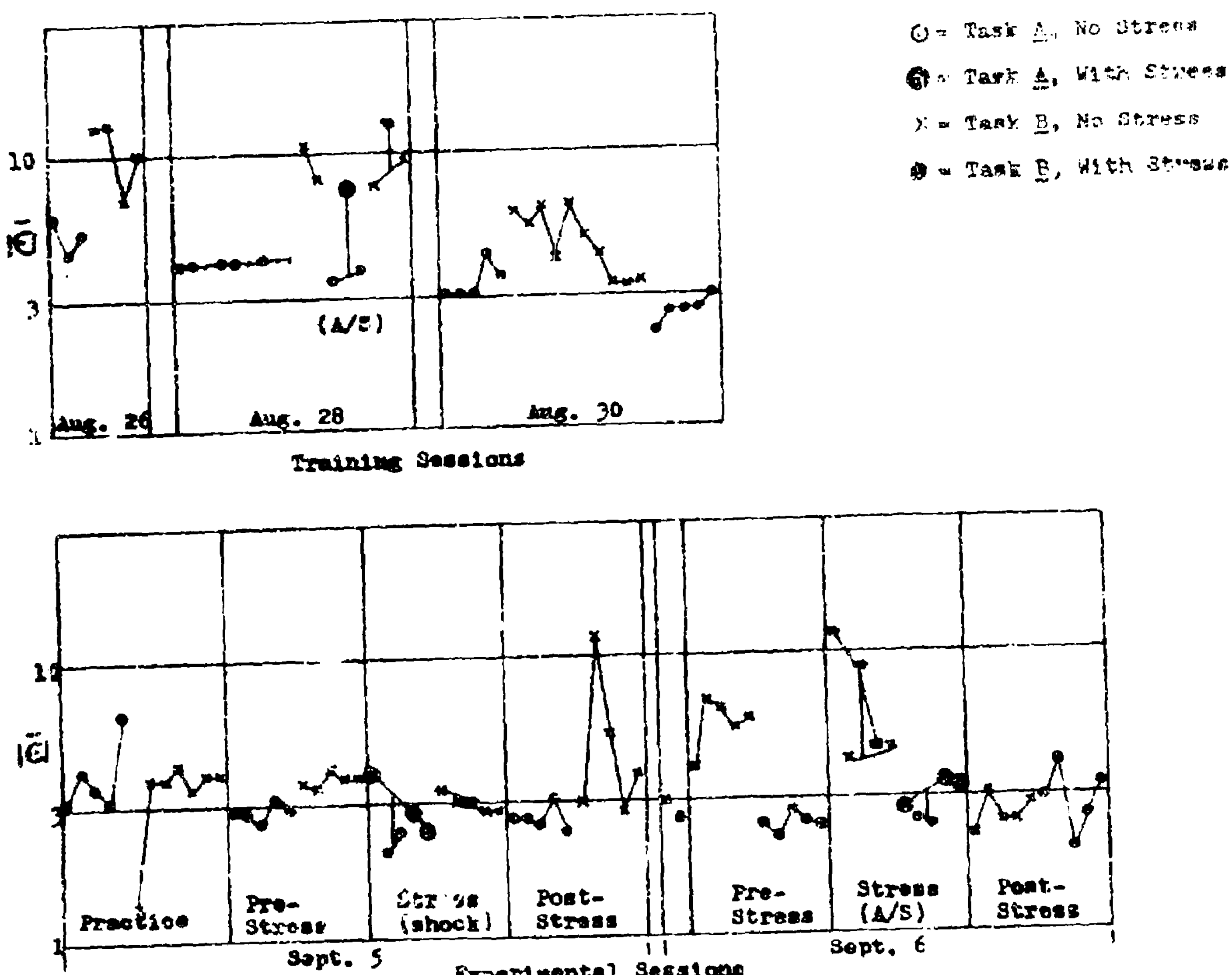


Fig. 22 Over-All Performance of Subject #15.

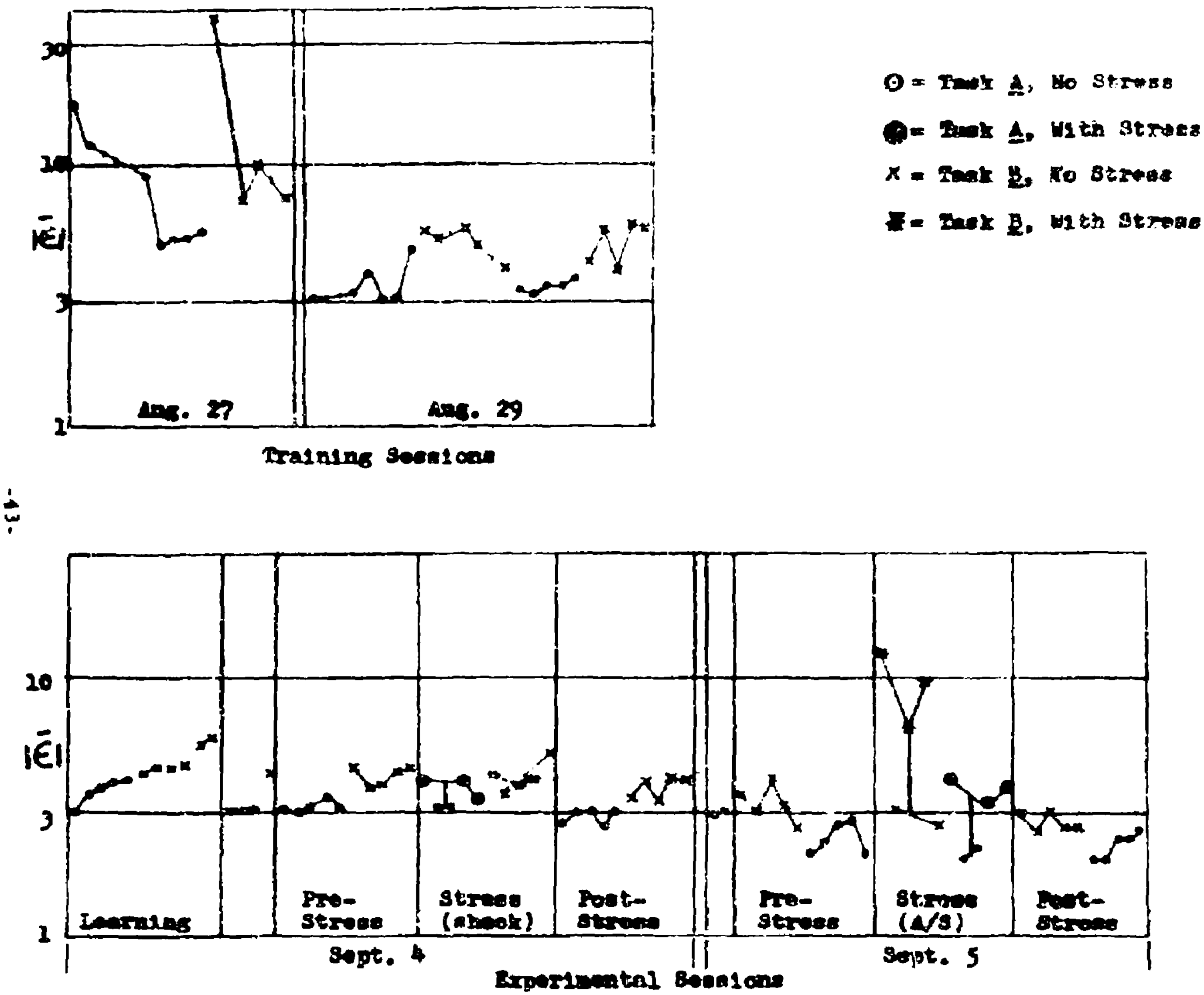


Fig. 23 Over-All Performance of Subject #13.

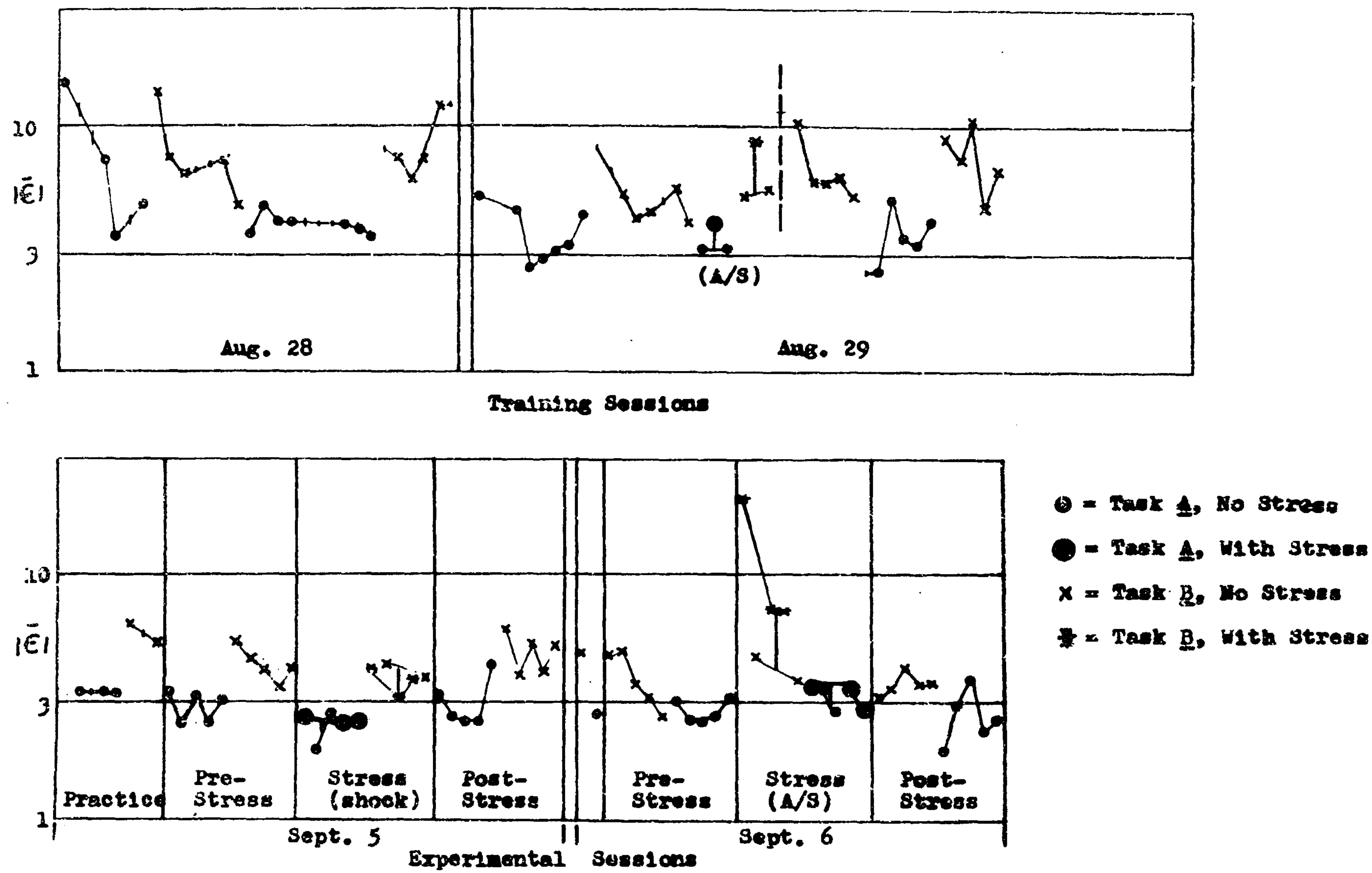


Fig. 24 Over-All Performance of Subject #14.

Experimental Sessions

Fig. 24 Over-All Performance of Subject #14.

(b) Auditory Shadowing, First Session.

After the first three Subjects had been trained in tracking on August 26th, they left the group to begin training on Auditory Shadowing. Training was conducted by Mr. Shectman following a scheme proposed by Dr. Mowbray of the Johns Hopkins University/Applied Physics Lab.

The Subject was introduced to the Shadowing with a series of learning tapes on which the digit rate increased steadily from one per second to rather more than 2 per second.

The first session of training for each man lasted about 20 minutes and the Subjects were considered proficient when they made approximately 2 mistakes per list. To reach this criterion took several separate sessions, all of which followed the appropriate tracking training session.

The digit lists used on the training tapes did not appear on the "stress" tapes used in the experiment, which were recorded separately to ensure that no Subject could learn the list.

(c) Tracking - Subsequent Sessions.

The first Subject trained, No. 17, was given a second training session on August 27. It was immediately obvious that he had profited considerably from watching the others on the previous day, since his first attempt with Task A gave an error of 5.1 mils and the final run of the set of 5 one minute runs gave an error of 3.7 mils. He then attempted Task B and his first score duplicated the final result of the previous day of 9.3 mils and steadily improved to 7.8 mils. At this point he was given a rest while a second Subject was given practice and a third session produced much the same result for Task A but an improved result for Task B (Figure 13).

The final training session with this Subject, August 30th, produced slightly better figures for Task A and much the same for Task B. By this time he was considered well trained in the Auditory Shadowing. He was given 3 more runs on Task A and B, with Shadowing applied on the central run in which his error increased about 50% for Task A and 100% for Task B (Figure 13).

All the other Subjects were given one or two additional practice runs on Task A and B before the experimental runs. In the case of Subjects Nos. 18, 19, 13, 14 and 15, the same tendency was found as was the case with the first Subject, No. 17, in that the results tended to be much the same over both the last two days of the practice sessions (Figures 19, 20, 22, 23 and 24.) In general, practice was completed by August 30th, but in the case of Subject No. 13, a final practice session was held on September 4th some 1/2 hour or so before the experimental session.

Summarized results of the training sessions are given in Table XI and it is immediately evident that six of the eight Subjects had attained much the same levels of proficiency at tasks A and B and that two Subjects were appreciably less accurate. In some cases the Subjects appears nearly as accurate on Task B as on Task A, but a study of the error ratio, in which results were compared relative to the "standard" performance of the highly trained Subject No. 1, thus eliminating the effect of changes in "stiffness", showed that at the same stiffness Task B was always at least twice the error of Task A. The results also showed that although the Subjects had reached an almost steady error, it was still nearly twice as great as the standard result for Task A.

It seemed likely that these Subjects would show a continued further improvement with long-continued practice. The difference was less marked in the case of Task B, probably reflecting the lesser amount of experience of S #1 with this task.

Some of the other Subjects were also given a one minute trial with Auditory Shadowing on each task, and in all cases tracking degraded considerably. It was therefore concluded that Auditory Shadowing at a rate of two digits per second was a suitable stressor and that no modification need be made to the experimental program. No Subject was given any experience with the electric shock.

Two of the Subjects produced slightly different results.

Subject No. 20 reached a satisfactory level with Task A on the second session but had some difficulty at first, with Task B in that his average error still exceeded 10 mils. However, in the 3rd session of training he did achieve better results, and this was confirmed in an additional training session on August 30th. (Figure 16)

Subject No. 16 had such difficulty with Task A on his first session that no attempt had been made to introduce him to Task B. On his second session, August 27th, however, his initial error was 18 mils as in the first session but he steadily improved during 10 one-minute runs for a final score of 4.2 mils.

He then made his first attempt at Task B and scored 29 mils reducing this in the course of 9 runs to 11 mils, which was considered satisfactory. His performance on Task B however, subsequently remained above the level of the group. (Figure 21)

Based on the results of training, Subjects were allocated an estimated training accuracy as given in Table XI, and this was used to divide the Subjects into two (equal) groups, I and II, paired off as to relative skill.

5.2 Results of Pre-Stress and Post-Stress Measurements.

On each of the two experimental days the Subjects tracked for 10 minutes to give 5 minutes Pre-Stress measurement on each task and for a further 10 minutes to give 5 minutes Post-Stress measurement on each task.

In addition to these, two minutes out of each minute run in the Stress period were actually unstressed.

Looking at the results in general in Figures 13, 16, 19, 20, 21, 22, 23, and 24, the simplest conclusion is that there appears to be no consistent difference between Pre-Stress and Post-Stress measurements. The general trend throughout the whole experiment for all Subjects is a slow improvement with time. This is particularly noticeable on Task A, which tends to be more consistent in its results than Task B (Figures 25, 26, 27 and 28).

Subject No. 15, on the first day, appeared to become very erratic on Task B in the Post-Stress, but we noticed at the same time that he apparently had become fatigued (Figure 22).

Another observation which may be significant is that in the case of 4 of the 8 subjects (Nos 14, 16, 18 and 20), the average of the 2 unstressed runs on Task A during the Stress session appears to be appreciably less than the average of the Pre-Stress and Post-Stress results (Figures 16, 20, 21 and 24). We are unable to suggest any reason for this effect, which was only marked wh n the electric shock was used as a stressor.

5.3 Results under the influence of stressors.

(a) Auditory Shadowing.

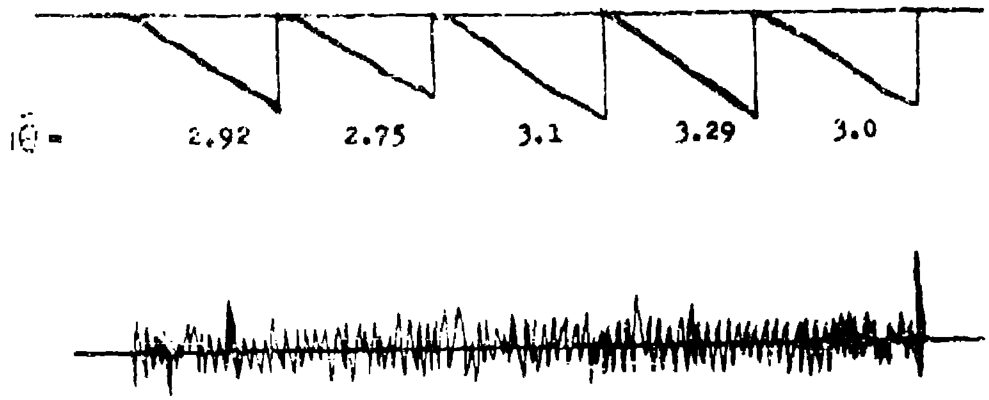
The effect of Auditory Shadowing was large for almost all subjects on either Task (Figures 29 and 30).

Preliminary trials had been made during the learning period (on 6 out of the 8 subjects) to determine whether the digit list was being run at sufficient speed to produce a measurable results.

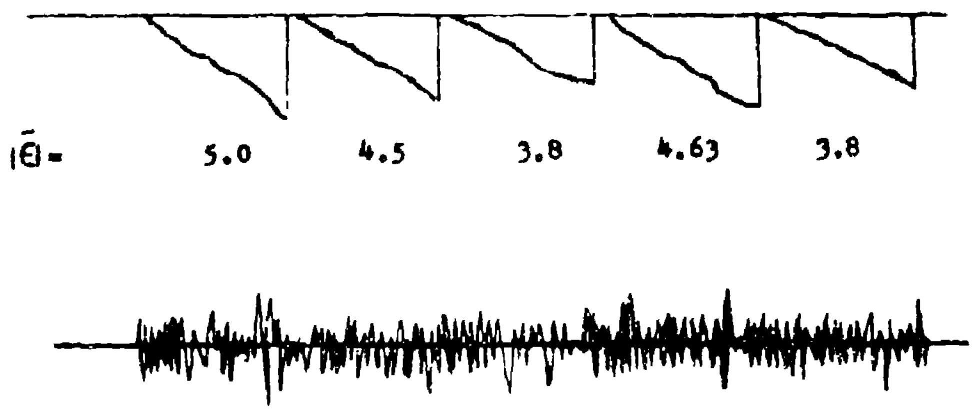
Results for Subjects Nos. 14, 15, 17, 18, 19, and 20 show that in every case the effect was large and apparently of significance compared to the random variations during the unstressed training runs (Figures 13, 16, 19, 20, 22 and 24).

The results of the Auditory Shadowing on tracking are summarized in Table XX. They are given as absolute mils error for the 3 "stressed" runs and may be compared with the "base" error attained at the end of training; with the mean of the Pre-Stress runs; the mean of the Post-Stress runs; and with the mean "unstressed" results (i.e., the two runs without A/S during the 5 minute "Stress" session. 0

Subject #17



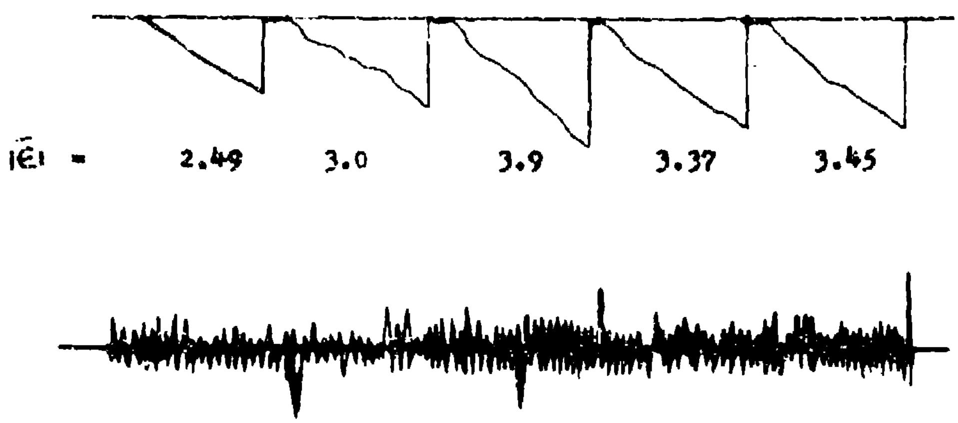
Task A
Stiffness... 158 mils/sec^2
Lag... 0 sec



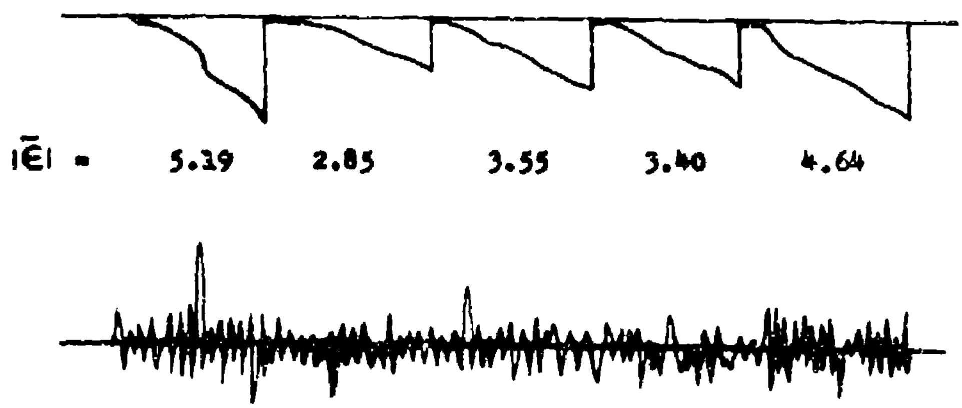
Task B
Stiffness... 91.2 mils/sec^2
Lag... 1.255 sec

Fig. 25 Pre-Stress Performance of Subject #17.

Subject #17



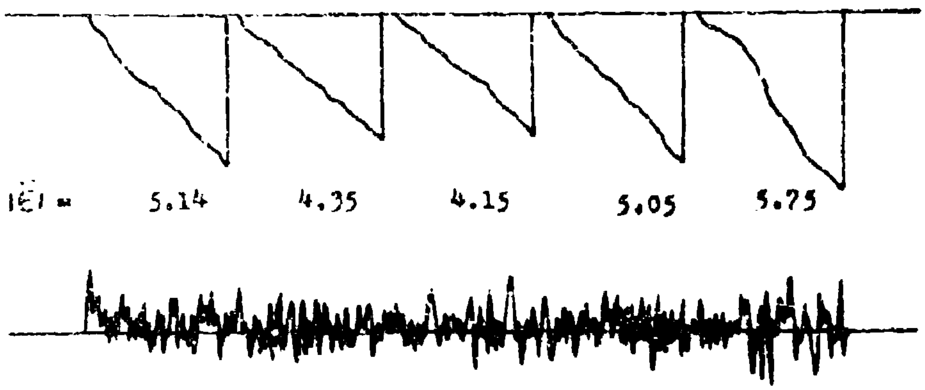
Task A
Stiffness... 158 mils/sec^2
Lag... 0 sec



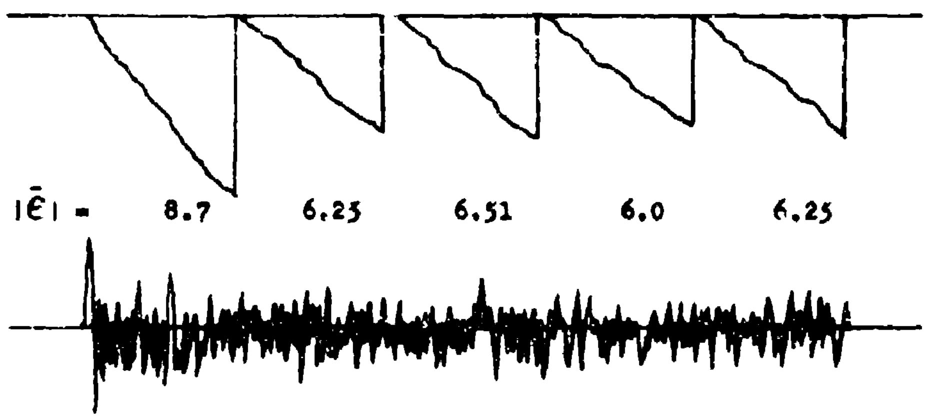
Task B
Stiffness... 91.2 mils/sec^2
Lag... 1.255 sec

Fig. 26 Post-Stress Performance of Subject #17.

Subject #20



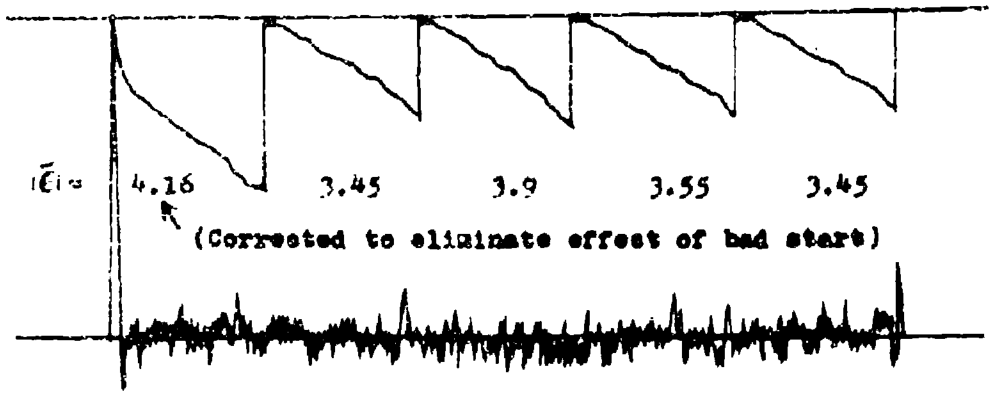
Task A
Stiffness... 158 mils/sec^2
Lag... 0 sec



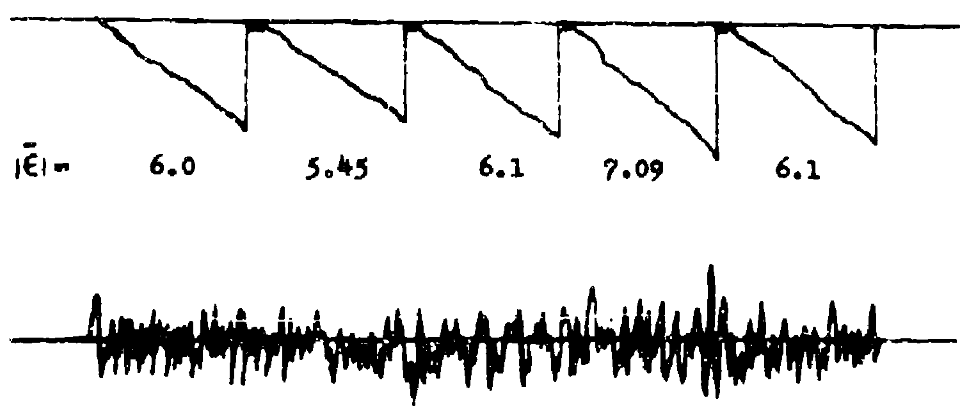
Task B
Stiffness... 158 mils/sec^2
Lag... 1.255 sec

Fig. 27 Pre-Stress Performance of Subject #20.

Subject #20



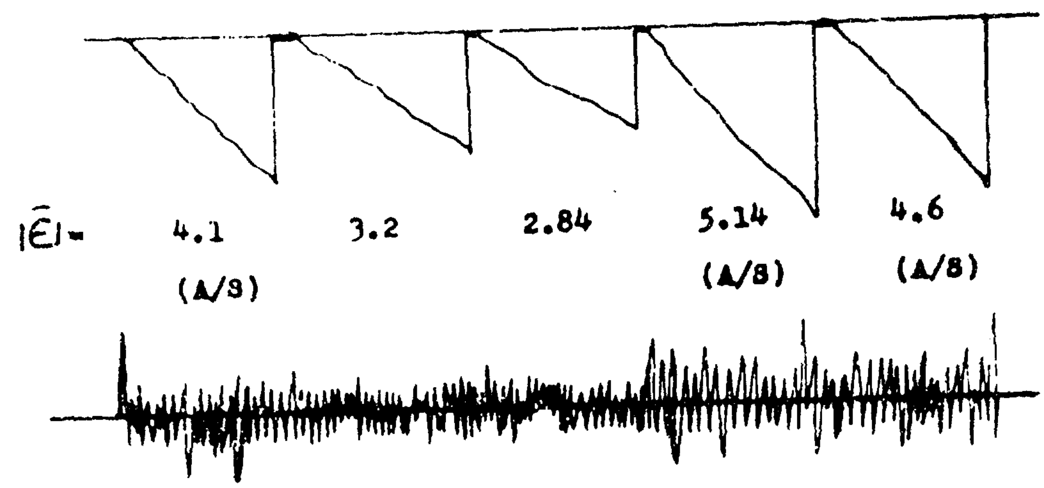
Task A
Stiffness... 158 mils/sec^2
Lag... 0 sec



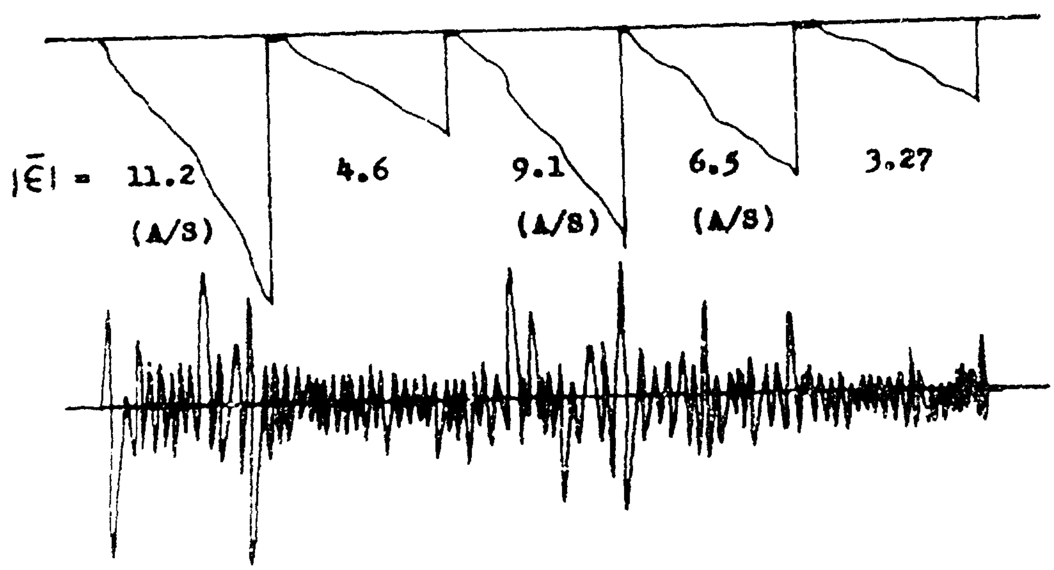
Task B
Stiffness... 91.2 mils/sec^2
Lag... 1.255 sec

Fig. 28 Post-Stress Performance of Subject #20.

Subject #17



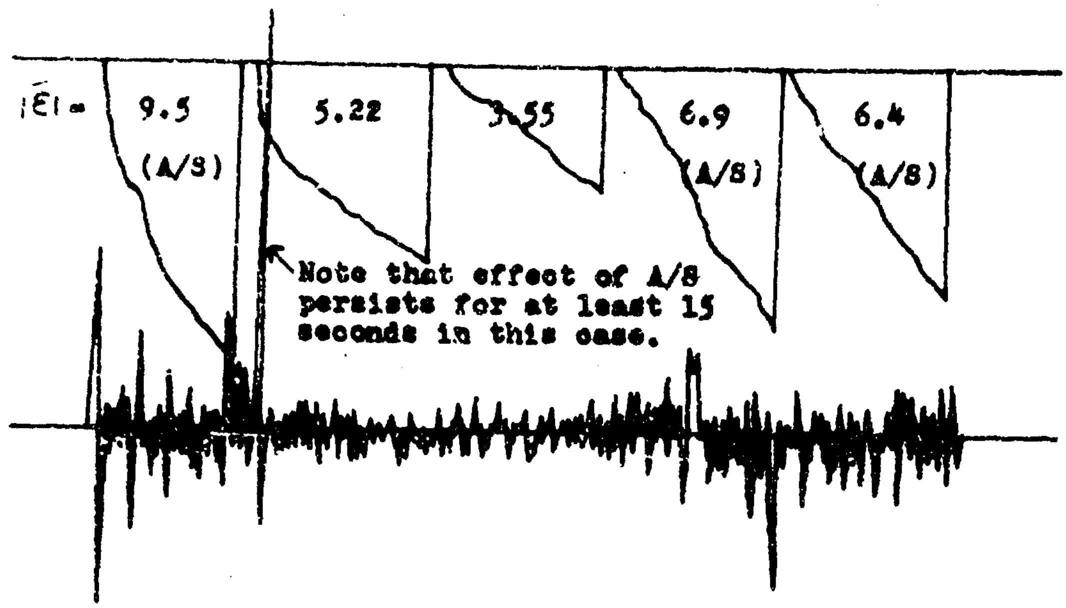
Task A
Stiffness... 158 mils/sec^2
Lag... 0 sec



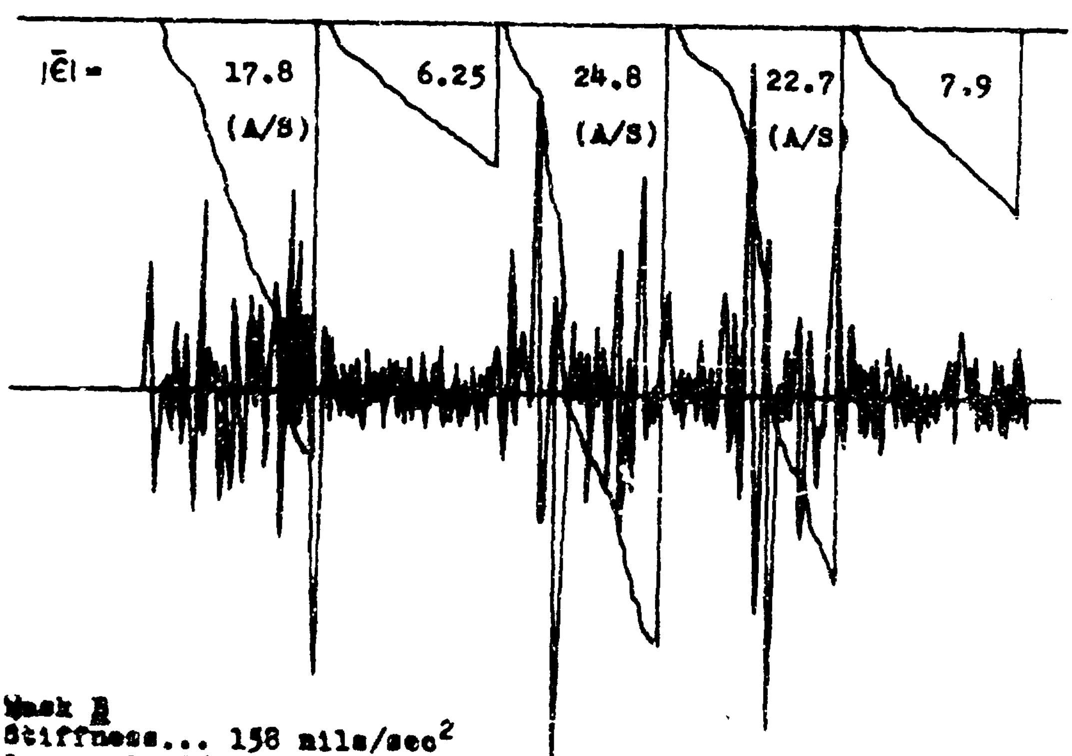
Task B
Stiffness... 91.2 mils/sec^2
Lag... 1.255 sec

Fig. 29 Effect of Auditory Shadowing on Subject #17.

Subject #20



Task A
Stiffness... 158 mils/sec^2
Lag... 0 sec



Task B
Stiffness... 158 mils/sec^2
Lag... 1.255 sec

Fig. 30 Effect of Auditory Shadowing on Subject #20.

The table also shows the number of mistakes made by the Subject in the digit list as recorded while he was tracking.

On examining the tracking results, the scatter appears to be rather high, but it is evident that, as the tracking and the Shadowing are competitive tasks, some Subjects under some conditions might have concentrated on tracking to the detriment of A/S and others might have concentrated on A/S to the detriment of tracking performance. This possibility can be examined by the following technique.

Figure 31 compares tracking error on Task B, measured in three different ways, with tracking error for Task A. It is apparent that no matter how results are analyzed, the tracking error for Subject No. 14 is always much greater relative to A than the average, and the tracking errors for Nos. 16, 18, and 19 appear to be consistently less than the average.

A similar plot for A/S errors for a total of 300 digits is given in Figure 32. It is shown in this case that the A/S errors for Subject No. 14 are appreciably less for Task B than for Task A while for Subject No. 18 -- the A/S errors are appreciably greater than average for Task B, as compared to Task A.

It seems very likely that Subject No. 14 was tending to concentrate on the A/S rather than the tracking for Task B (or conversely for Task A) whereas Subject No. 18 may have tended to concentrate on tracking to the detriment of A/S. This can be checked by devising some consolidated score to take account of the accuracy of both tracking and Shadowing. A simple example of such a score is the geometric mean of the separate scores. This is plotted in Figure 33 for two separate measures of tracking error and in either case results in greatly reduced scatter.

The problem of analyzing the results of Auditory Shadowing trials is discussed further in the third part of this final report.

(b) Electric shock.

The effect of the electric shock is very small for most Subjects tested. In fact, in many cases with Tracking Task A subjects actually performed better during the runs when the shock was administered than the average of the Pre-Stress and Post-Stress runs (Figures 13, 16, 21 and 24). If there is any significant effect to be noted at all, there is a suggestion in some S s of anticipation. Sometimes the Pre-Stress level or the first run in the shock series does show a degradation due apparently to worry in anticipation of the shock (Figures 13, 22, and 34).

Since no S s had experienced the shock previously this would be expected, and the Subjects, when interrogated did confirm that they were somewhat worried by the thought of the shock until they had experienced it. Once they received one or two shocks they felt they were able to disregard it.

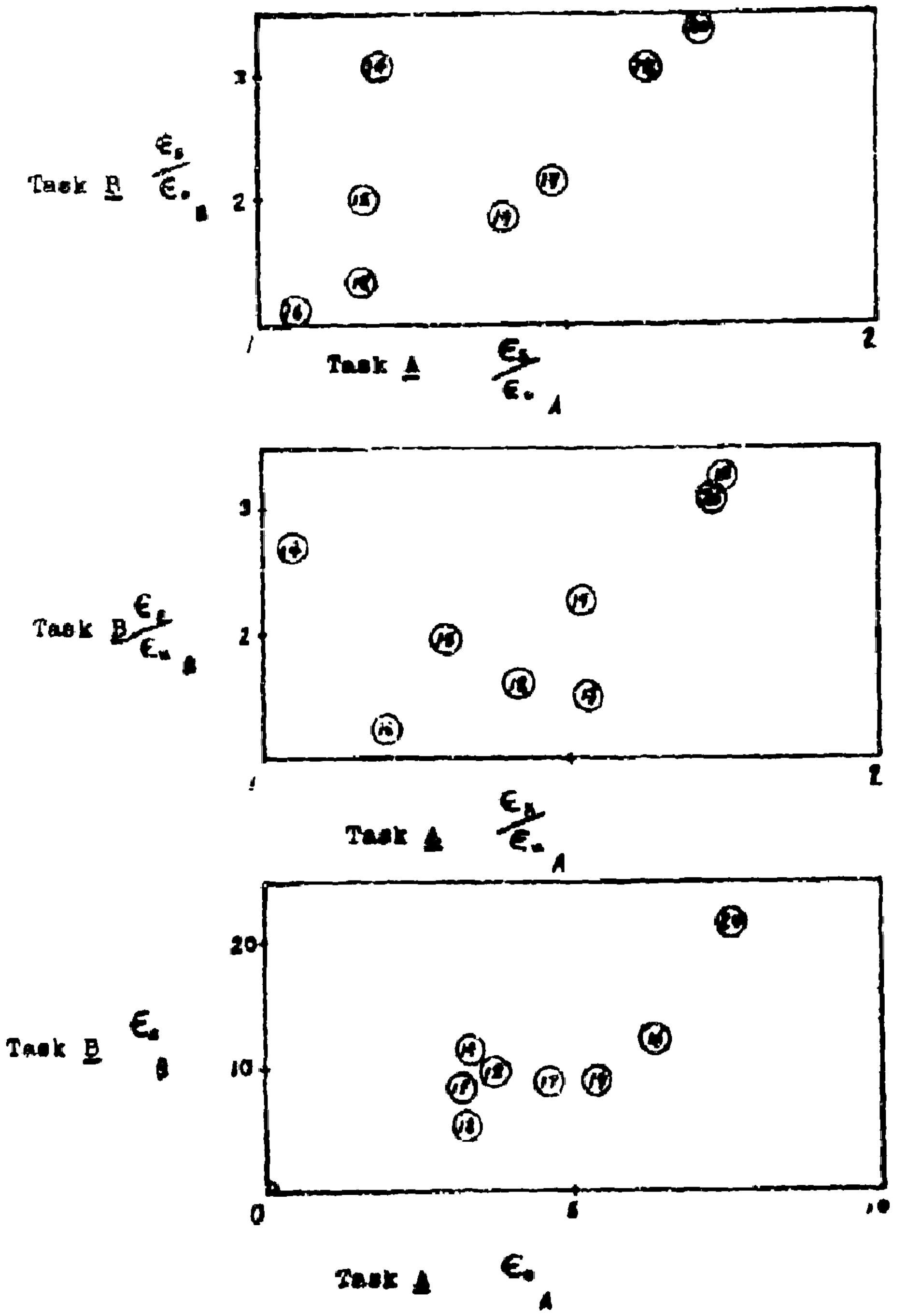


Fig. 31 Comparison of Tracking Errors on Tasks A and B.

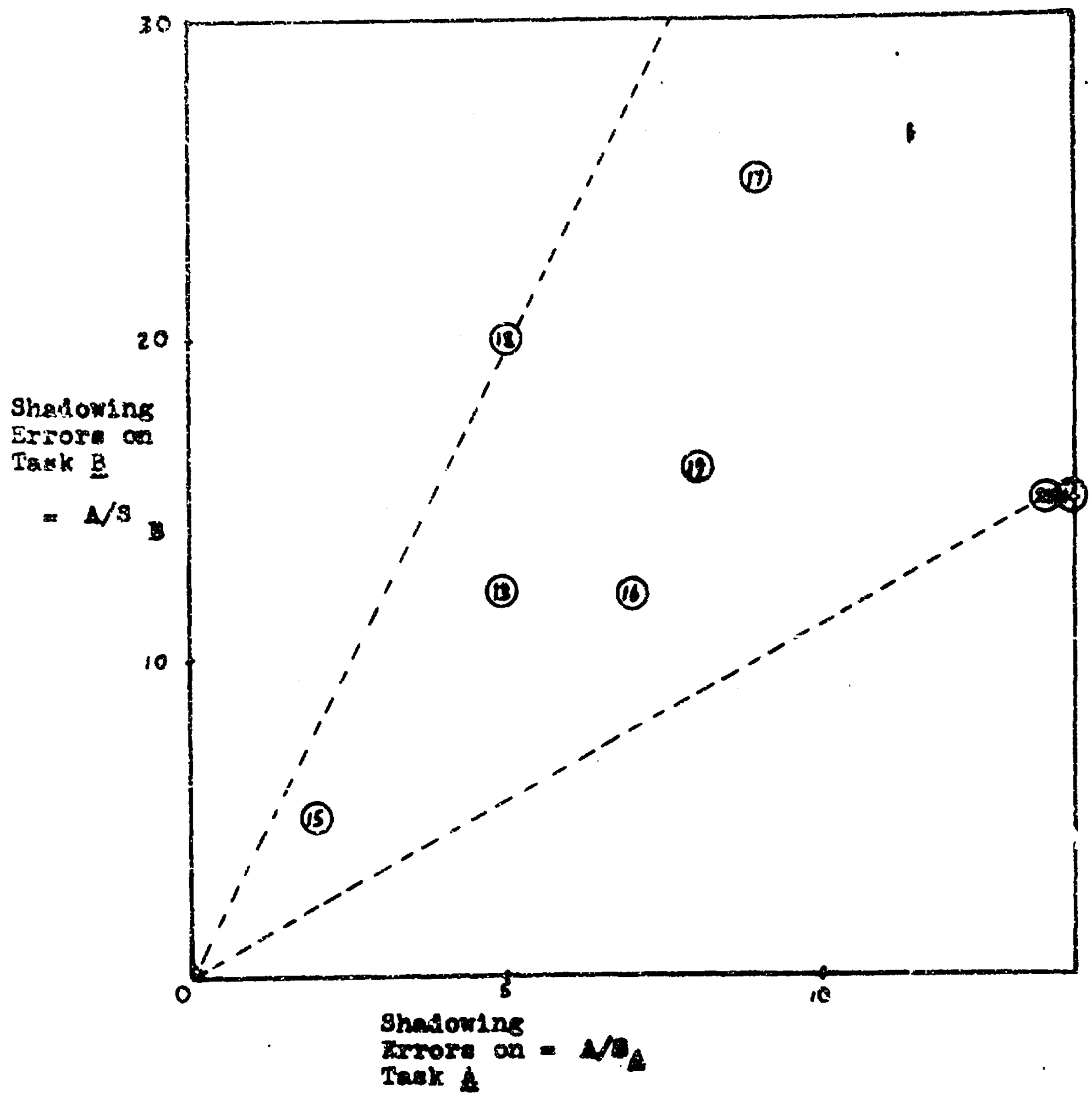


Fig. 32 Comparison of Auditory Shadowing Errors on Tasks A and B.

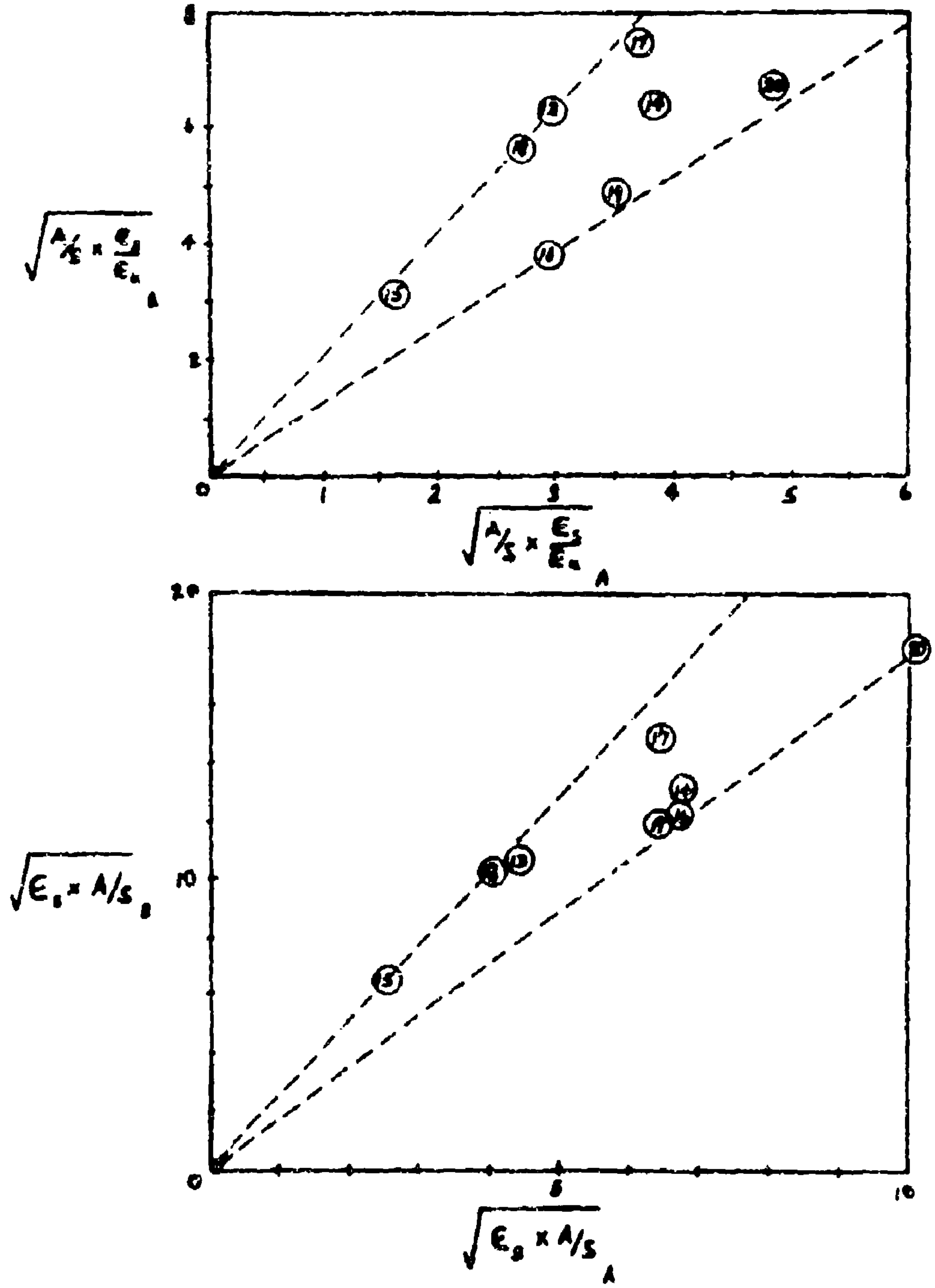


Fig. 33 Comparison of Consolidated Errors on Tasks A and B.

Subject #17
Stiffness... 91.2 mils/sec^2
Lag... 1.255 sec
Task B

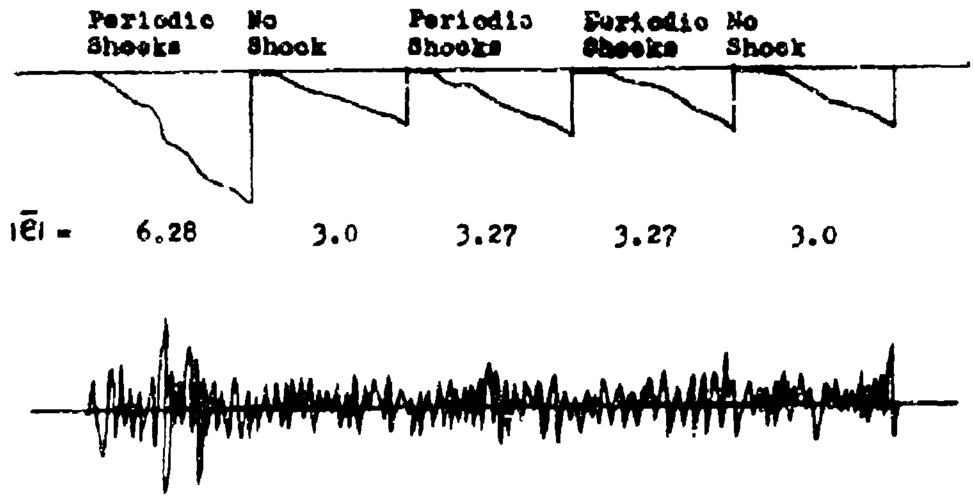


Fig. 34 Effect of Electric Shocks on Subject #17.

The tests on these Subjects and detailed examination of records supported by experiments on the writers themselves suggest that the immediate effect of an unexpected occasional shock can only be to disrupt a single control movement. Since, in the case of Task A the Subject will make perhaps 120 control movements per run and receive 3 shocks and in the case of Task B he will make perhaps 85 control movements per run, it is obvious from Appendix II that the effect on Task A should only be of the order of 10% increase in error and on Task B perhaps 15% at the most.

In a subsidiary experiment the writers were subjected to frequent electric shocks at the rate of about one every four seconds giving perhaps 15 shocks per run but the resulting increase in error which could then be determined was only 5% to 20% above the no-shock condition.

6. CONCLUSIONS

(1) The improved technique used to train Subjects in Tasks A and B was successful, and all Subjects gave good tracking performance after about 15 minutes practice on each Task, and asymptotic performance after about 40 minutes.

(2) In some cases, there was a continued slow improvement in performance throughout the experiment.

(3) Group training of Subjects is successful, as it requires less total training time.

(4) Auditory Shadowing has a major effect on Task B for all Subjects, a much less -- but appreciable -- effect on Task A.

(5) Subjects differ considerably in their sensitivity to the effects of Auditory Shadowing.

(6) A combined measure of performance on both Auditory Shadowing and tracking is more consistent than either individually.

(7) Mild electric shocks have little effect.

(8) The separate 5 minute Pre-Stress and Post-Stress periods showed no appreciable effect.

(9) There was, however, in some cases an appreciable increase in tracking errors during the Stress period but before the S received his first electric shock.

FINAL REPORT

July 1962 - Jan 1964

FURTHER WORK ON THE USE OF TRACKING TASKS AS INDICATORS OF STRESS

PART III

THE ANALYSIS OF AUDITORY SHADOWING EFFECTS ON TRACKING

by

Norman K. Walker

USAMEDS CONTRACT No. DA-49-193-MD-2369

PART III

THE ANALYSIS OF AUDITORY SHADOWING EFFECTS ON TRACKING

1. INTRODUCTION

Part II of this report showed that Auditory Shadowing and tracking were essentially similar tasks competing for the Subject's attention, and that the greater part of the experimental scatter of the results comes from an unconscious and variable decision on the part of the operator to concentrate on one task rather than the other.

In this section of the report, a procedure is developed which translates the tracking error readout into errors of decision, which are then directly comparable to the errors in the digit list as read back.

2. A SIMPLE THEORY OF TRACKING ERROR DEGRADATION

When performing Auditory Shadowing a mistake appears as the complete omission of a response or the wrong response. Both, we feel, are equal in weight and are proportional to one missed "bit" of information.

When performing tracking, the Subject commonly exhibits a particular frequency of oscillation, on which is super-imposed an oscillation of lower frequency. Subjectively analyzing his own and the other Subjects' experience, the writer finds that the low frequency component is generated by the complete omission of signals, or by a late appreciation of visual cues which leads to the omission of a signal. Hence, the change in mean error can be correlated with a particular number of missed signals, and this will correlate with the errors in the digit list.

Consider the perfect oscillation in Figure 35a of period t, and amplitude $\pm$ 1 unit.

Then $\epsilon \text{ max.} = 1/2 \ \ddot{\Delta} \text{ max.} \ (t/4)^2$ and $|\epsilon| / \epsilon_{MAX} = 2/3$

$\therefore \ |\epsilon| = 1/48 \ \ddot{\Delta} \text{max.} \, t^2$

Now there will be two stick movements per cycle, so if the period of one oscillation is t seconds, there will be $2/t$ stick movements per second. Or $|\epsilon| = 1/12 \ddot{\Delta}\text{max.} (1/n)^2$ where n = stick movements/second.

Now consider the case in Figure 35b, when a series of correct

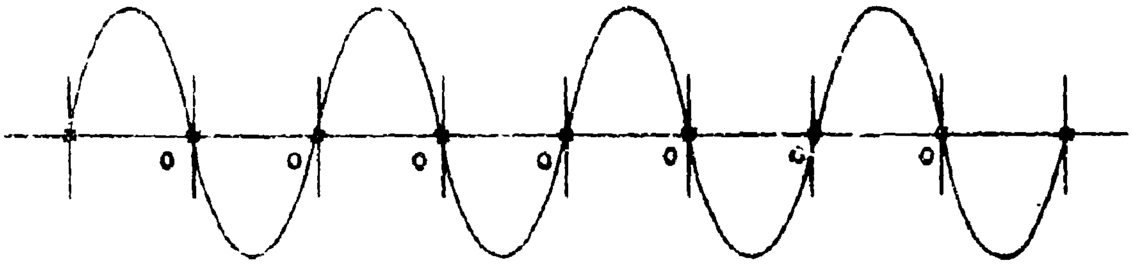


Fig. 35a Idealized "Rubric" Tracking (Unit Amplitude).

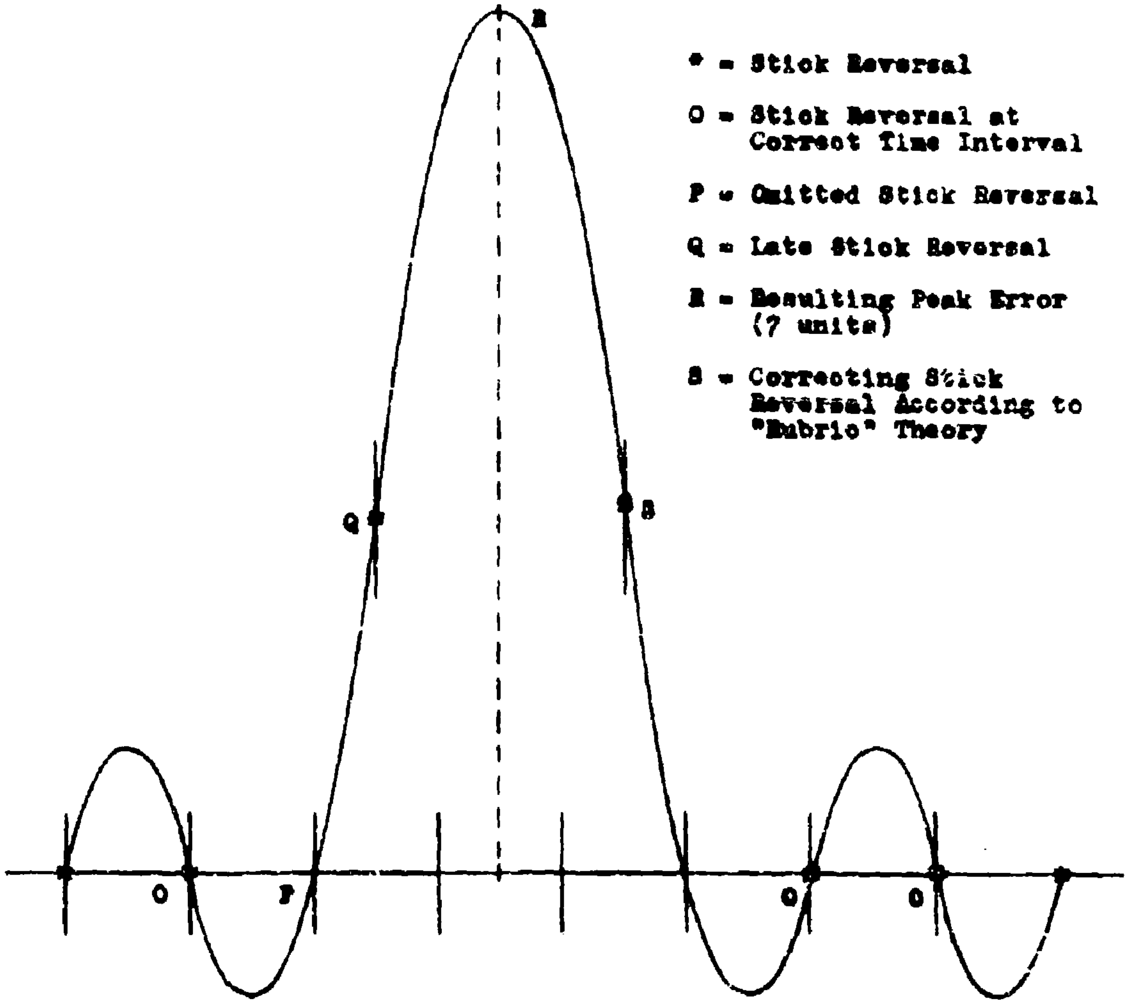


Fig. 35b Idealized "Rubric" Tracking with a Single Late Signal.

decisions is followed by one large excursion and then a further series of correct decisions.

Suppose the correct stick movement is missed at point [illegible] not applied until Q, when the oscillation should have reached a peak. A large disturbance of 7 times the original peak error will then peak at R, and using "Rubric" tracking, wiii then be corrected by a stick movement at S, which will restore the original oscillation both in amplitude and phase. *

Note that each such excursion disrupts the original pattern for three half-cycles, and that the mean amplitude of the new large disturbance is 4.22.

Suppose that "δ" such disturbances occur in the total time of the experiment, which would otherwise include N_o half-cycles.

Then the total accumulated modular error will be

$$(N_o - 3\delta)\ (2/3) + 2/3\ N_o$$

This will yield an error ratio of:

$$1 - 3\ \delta/N_o + 4\tfrac{1}{2}\quad \delta/N_o\ (4.22)$$

$$= 1 + 16\ \delta/N_o$$

Now $N_o = T$ (duration of experiment) x n (number of stick movements per second.

$$N_o = T\sqrt{\frac{\ddot{\Delta}_{max}}{12|\varepsilon|_o}}$$

and can be calculated from the observed mean error in the "base" period.

"δ" can then be derived from the observed proportional increases in error under stress, and will presumably be directly comparable with errors in the words list. Note that this determination of δ reaches a maximum value for a symmetrical oscillation as shown in Figure 36, where each correct stick movement is followed by a late movement. For this case, the error ratio is 8, and $\delta = 1/5\ N_o$. (It is possibly significant that at about this error ratio we believe that combat results show a sudden increase in error.)

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* This very simple description agrees well with the operators' subjective descriptions of how mistakes occur, although in practice the actual tracking traces are complicated by the small variations in operators response time which occur even without definite "mistakes."

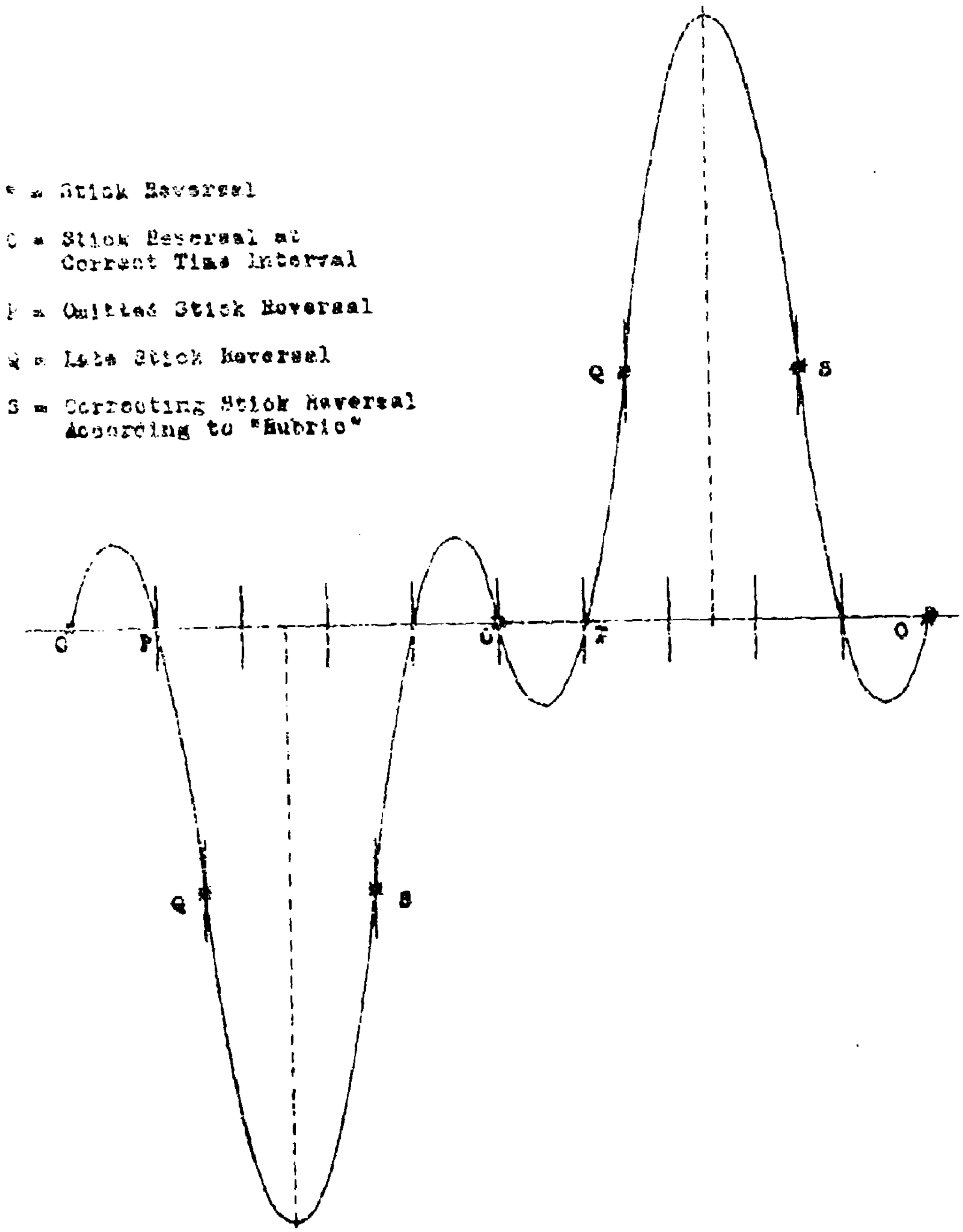


Fig. 36 "Rubric" Tracking with Successive Late Signals.

Substituting τ = 162 seconds (total for three 54-second runs)

$$\ddot{\Delta}\ \text{max.} = 158 \quad (\text{Task } \underline{A})$$
$$91.2 \quad (\text{Task } \underline{B})$$

we have $N_o = 588/\sqrt{|\epsilon|_o}$ (Task $\underline{A}$)

$N_o = 447/\sqrt{|\epsilon|_o}$ (Task $\underline{B}$)

Results of this computation are collected in Table XXII.

3. AN IMPROVED METHOD OF SMOOTHING

Let us now plot the total number of tracking errors over 3 runs, δ, against the total number of Auditory Shadowing errors, as in Figure 37. Suppose the result for one Subject falls at point P. Now it is clear that the Subject may choose to concentrate on either Shadowing or tracking at any time, and that working at optimum performance this must result in some form of trade-off curve.

To take the simplest case, we might assume that the total effective error is constant. Suppose on the average that δ = k (A/S). Then in this case, the locus of this condition will be a straight line through P, of slope -k as shown, and a "smoothed" value of P would be the point Q_1.

If this seems unreasonable, in that perfect performance is unattainable, one might assume that a zero error in one coordinate must imply infinite error in the other, and the resulting locus will be hyperbolic, giving a smoothed value of Q_2.

Conversely, one could assume that the R. M. S. value of the two errors is constant. In this case the locus will be a circle about the origin, giving a smoothed value of Q_3.

However, for all the cases considered, the divergence from the mean is not so great that the difference between these different forms of smoothing is important. Q_1, Q_2, and Q_3 will all give a better fit to the data than P. Hence we will assume that linear smoothing is acceptable as being the simplest to use.

Figure 38 shows a plot of δ versus A/S for both Tasks $\underline{A}$ and $\underline{B}$. Very roughly we can see that δ = A/S is a good approximation in both cases, and the smoothed results listed in Table XXII are corrected by the linear method, using the relation

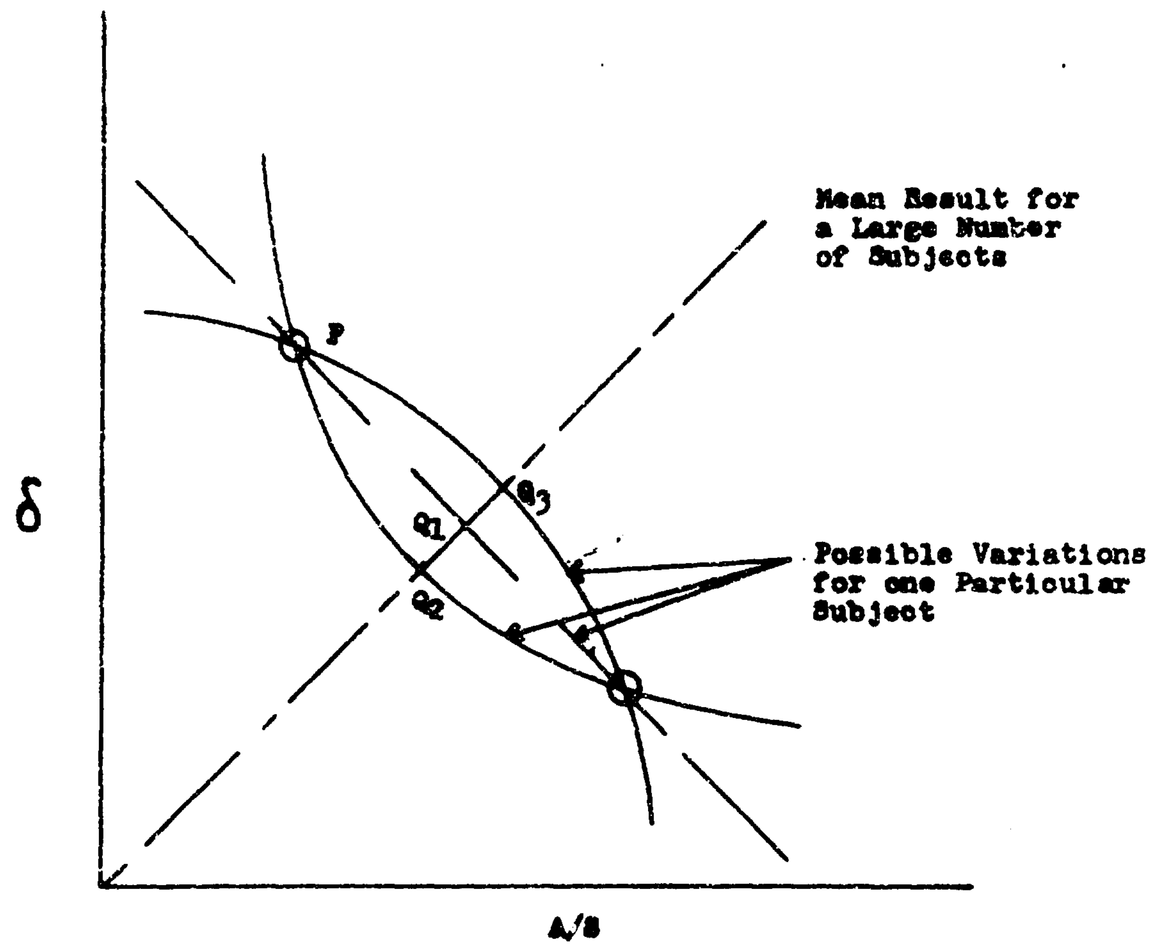
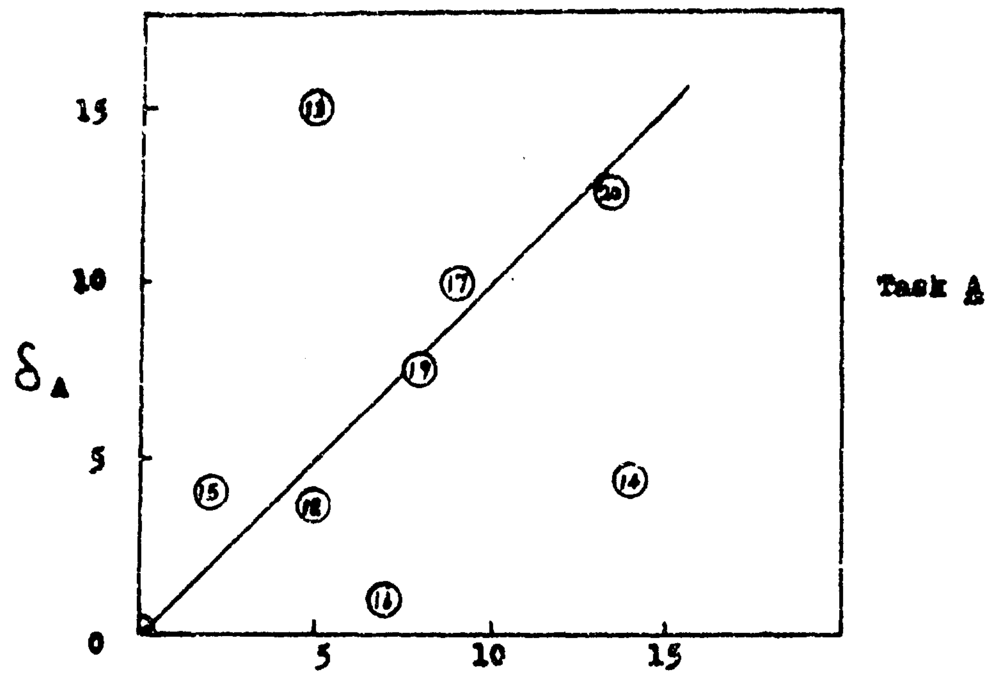


Fig. 37 Possible Forms of Smoothing Combined Auditory Shadowing and Tracking Errors.



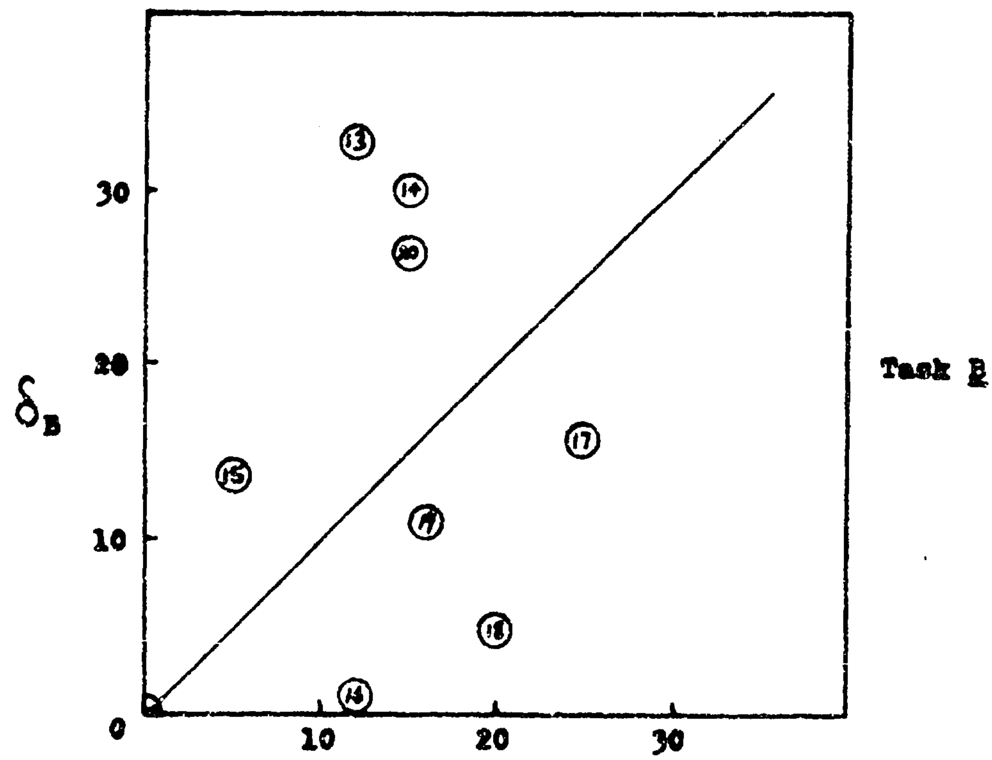


Fig. 38 Comparison of Total Number of Tracking Errors and Auditory Shadowing Errors. (Tasks A and B).

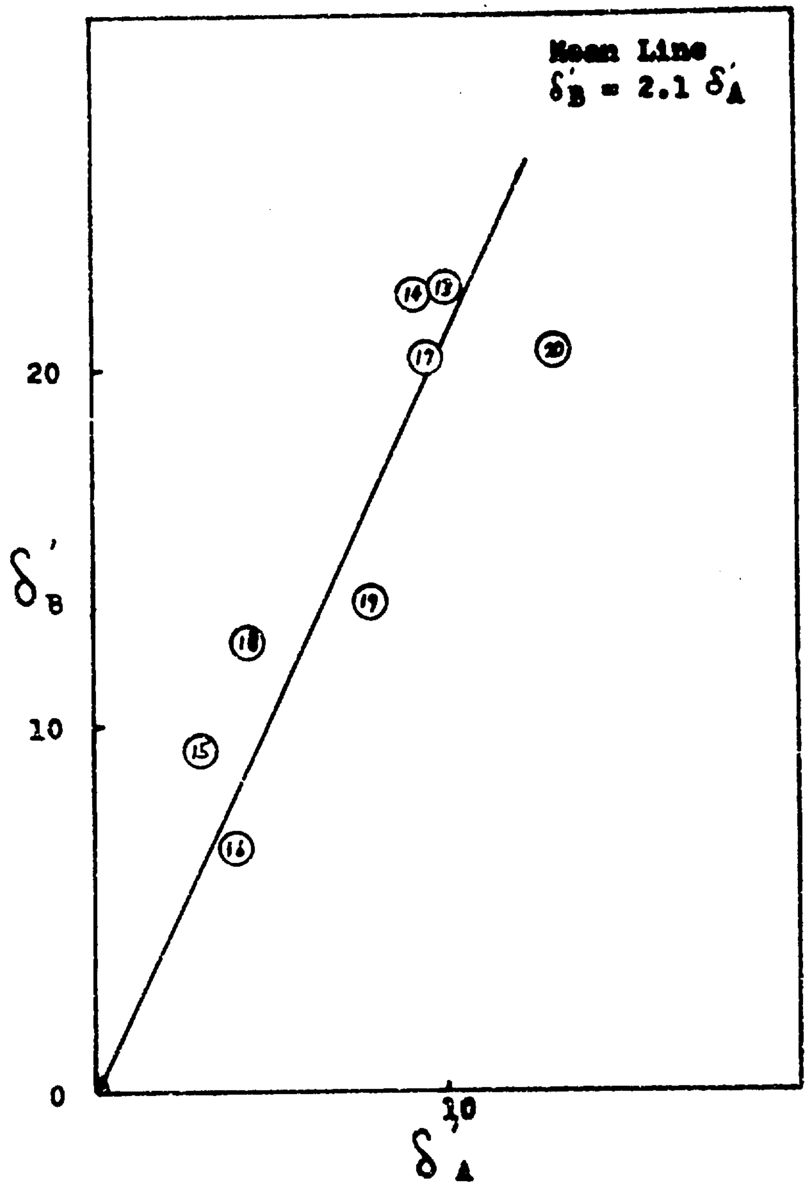


Fig. 39 Comparison of Total "Smoothed" Tracking Errors for Tasks A and B in the Presence of Auditory Shadowing.

$$\delta' = \frac{\delta + A/S}{2}$$

A cross plot of δ'_A versus δ'_B, (which of course is the same as plotting A/S'_A versus A/S'_B), using the corrected values (Figure 39) shows that a very satisfactory degree of consistency has now been obtained as compared to the raw data plots of Figure 31 and even the "consolidated" plot of Figure 33, both given in Part II of this report.

From the smoothed values it is possible to derive a corrected value for the error ratio. Figure 40 compares the uncorrected and corrected values of the error ratio by assuming a fixed arbitrary variation of some stress parameter with error ratio for Task B, and then assuming that the same values of this stress parameter hold for Task A. (Note that this implies we are considering a variation of increase in tracking error ratio from subject to subject due to the presence of auditory shadowing while executing two different tracking tasks. It does not mean that the position of the points along the horizontal axis defines an absolute stress level, though it is likely to be related to one. Clearly we would expect that if Auditory Shadowing and Tracking are competing tasks then a given Subject would be more highly stressed while performing Task B than Task A.) The results show that the effect of Auditory Shadowing on tracking accuracy, when plotted in this particular manner, is about 30% as much for Task A as for Task B whether raw data or smoothed results are used but that in the latter case the scatter is greatly reduced. This result of course holds for each Subject individually, but the absolute amount of the degradation varies from Subject to Subject and is presumably a measure of the individual's sensitivity to A/S as a stressor.

The effect of smoothing on the Auditory Shadowing scores may be even more dramatically demonstrated by using the same arbitrary values of the stress parameter, though it is now very difficult to see what the latter defines. Figure 41 gives a plot of the Auditory Shadowing errors against the arbitrary stress scale using both raw and smoothed results. The former are very scattered indeed, and all one can say is that the errors seem to be greater in the case of Task A than Task B. However, using the smoothed data there is no doubt that the increase in error with Task B is about 2.1 times that for Task A.

Since this improvement in the consistency of the A/S results is obtained at the same time as there is an improvement in the consistensy of the tracking results the smoothing process must be reckoned successful.

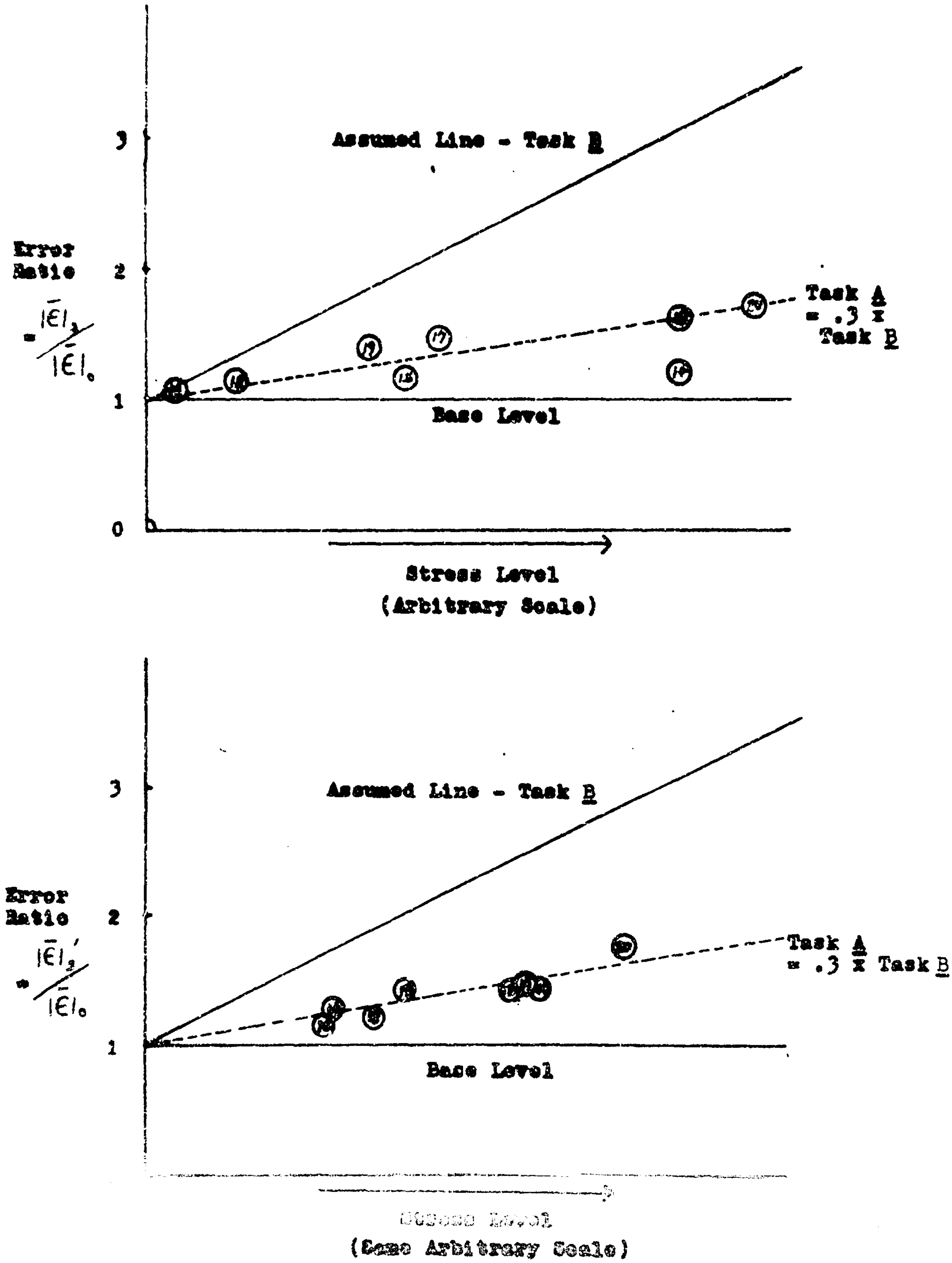


Fig. 30 Comparison of the Effects of A/S Stress on Tracking Errors Raw Data and Smoothed Results.

4. COMPARISON WITH COMBAT STRESS AND AN ABSOLUTE "STRESS LEVEL"

The increase of tracking error ratio per unit increase in stress level, as shown in Figure 40, is only about 30% as much for Task A as for Task B. References 4 and 5 show that almost exactly the same result holds for the effect of combat stress, so the inference is very strong that the interference effects due to Auditory Shadowing are in fact similar in character to some features of the combat situation which cause degradation in tracking performance, implying that combat degradation may be due to some sort of "information overload."

In Part I it was suggested that a suitable definition of a unit increase in stress might be a 100% increase in tracking error ratio with Task $\underline{A}$ (or of 1/0.3 with Task $\underline{B}$). Absolute "stress levels" assuming a linear variation are listed in Table XXII and are very consistent for the two Tasks, but vary considerably from one Subject to another.

5. CONCLUSIONS

(1) Unstressed tracking may be equated to an idealized tracking condition of regular oscillations with amplitude dependent on the "decision rate" or rate at which the operator decides to move and then moves the stick. The increase in error due to stress can be considered to be caused by the delay and subsequent omission of two successive decisions at intervals during a run.

(2) The average number of correct "decisions" in the unstressed case, "N_o", and the total number of "decision errors" (δ) may be deduced from the mean basic tracking error $|\bar{\epsilon}|_o$, and the stressed tracking error $|\bar{\epsilon}|_s$ by using the formulae:

$$N_o = T\sqrt{\frac{\Delta_{max}}{12\,|\bar{\epsilon}|_o}}$$

$$\delta = \left(\frac{|\bar{\epsilon}|_s}{|\bar{\epsilon}|_o} - 1\right) \times N_o/16$$

where T = total duration of the stressed run, in seconds.

(3) At any time under stress, the Subject may react by failing to give the correct decision in tracking, or by failing to give the correct response in Shadowing. To remove this anomaly a "smoothed" tracking error is determined as the mean of the tracking errors and the Auditory Shadowing errors in the same period of time.

(This is, of course, numerically equal to the "smoothed" Auditory Shadowing errors.)

(4) The total number of "smoothed" tracking errors is 2.1 times as great with Task B as with Task A.

(5) These tracking errors can then be converted back to a smoothed tracking error ratio. $|\epsilon|_S/|\epsilon|_L$ and the rate of increase of this ratio with stress is 3.3 times as great for Task B as for Task A.

(6) If it is assumed that the severity of the stressed environment is proportional to the increase in tracking error ratio, and that unit severity corresponds to 100% increase in error for Task B, then the "environmental" stress index reached by the various Subjects in the group ranges from 0.16 to 0.65. This is still not an absolute "stress" index, but it is probable that further work on these lines will lead to one.

(7) The excellent agreement between the combat degradation effects and the effects of Auditory Shadowing encourage the hope that such distraction tasks may be an effective laboratory substitute for combat, though much more work on this subject is required.

Fig. 42 The latest type of Zero Input Tracking Analyzer (Type III B) with Visicorder and hand control

TABLE I

Typical Digit List #2

To be read aloud to subject at 2 digits per second

1)	2	23)	2	45)	2	67)	2	89)	2
2)	1	24)	2	46)	1	68)	1	90)	2
3)	2	25)	2	47)	1	69)	1	91)	1
4)	1	26)	2	48)	1	70)	2	92)	2
5)	1	27)	1	49)	2	71)	1	93)	1
6)	2	28)	2	50)	1	72)	1	94)	2
7)	2	29)	2	51)	1	73)	2	95)	2
8)	2	30)	2	52)	2	74)	1	96)	1
9)	1	31)	1	53)	1	75)	1	97)	1
10)	1	32)	2	54)	2	76)	1	98)	2
11)	1	33)	7*	55)	2	77)	2	99)	6*
12)	2	34)	2	56)	2	78)	2	100)	2
13)	1	35)	1	57)	1	79)	2	101)	2
14)	2	36)	1	58)	2	80)	2	102)	1
15)	2	37)	1	59)	2	81)	1	103)	1
16)	1	38)	2	60)	2	82)	1	104)	2
17)	1	39)	2	61)	1	83)	1	105)	2
18)	2	40)	2	62)	1	84)	2	106)	1
19)	2	41)	1	63)	1	85)	2	107)	2
20)	2	42)	2	64)	2	86)	2	108)	1
21)	2	43)	2	65)	2	87)	1	109)	1
22)	2	44)	1	66)	4*	08)	1	110)	1

* Special "key" digits

TABLE II

EXPERIMENTAL DESIGN

PRE-STRESS	STRESSOR (SHOCK)	POST-STRESS
	PERIOD I	
Group I A* B*	A B	A B
	(Aud. Shad.)	
Group II A B	A B	A B
	PERIOD II	
	(A/S)	
Group I B A	B A	B A
	(shock)	
Group II B A	B A	B A

* Task A = Lag O, Gain 6

* Task B = Lag 3, Gain 5

TABLE IIIa

LEARNING FIGURES

SUBJECT:	13	DATE:	Aug. 27
GROUP:	1	SESSION:	First

Mean Integrated Error $\lvert\bar{\epsilon}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
17.8 mils	A	158 mils/sec^2	0 seconds
12.0	A	158	0
	Three-minute-instruction		
9.3	A	158 mils/sec^2	0 seconds
5.05	A	158	0
5.3	A	158	0
5.3	A	158	0
5.7	A	158	0
38.6	B	91.2	1.255
	One-minute-instruction		
7.6	B	91.2	1.255
10.1	B	91.2	1.255
	One-minute-instruction		
10.5	B	91.2	1.255

TABLE IIIh

LEARNING FIGURES

SUBJECT: 13 DATE: Aug. 29
GROUP: 1 SESSION: Second

Mean Integrated Error $\overline{\|\epsilon\|}$	TASK	$\ddot{\Delta}_{max}$	LAG
3.29 mils	A	158 mils/sec^2	0 seconds
	Two-minute-instruction		
3.64	A	158	0
3.9	A	158	0
3.2	A	158	0
3.29	A	158	0
4.97	A	158	0
5.6	B	91.2	1.255
5.3	B	91.2	1.255
	One-minute-instruction		
5.86	B	91.2	1.255
5.05	B	91.2	1.255
	One-minute-instruction		
4.1	B	91.2	1.255

TABLE IIIc

LEARNING FIGURES

SUBJECT: 13 DATE: Aug. 29
GROUP: 1 SESSION: Third

Mean Integrated Error $\lvert\bar{\epsilon}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
3.45 mils	A	158 mils/sec^2	0 seconds
3.2	A	158	0
3.55	A	158	0
3.55	A	158	0
3.7	A	158	0
4.35	B	91.2	1.255
5.7	B	91.2	1.255
3.95	B	91.2	1.255
6.0	B	91.2	1.255
5.7	B	91.2	1.255

TABLE IIId

LEARNING FIGURES

SUBJECT:	13	DATE:	Sept. 4
GROUP:	1	SESSION:	Fourth

Mean Integrated Error $\lvert\bar{\varepsilon}\rvert$	TASK	$\ddot{X}$ max	LAG
Practice before first experimental run			
3.0 mils	A	158 mils/sec^2	0 seconds
3.65	A	158	0
3.8	A	158	0
4.0	A	158	0
4.0	A	158	0

4.35	B	91.2	1.255
4.6	B	91.2	1.255
4.6	B	91.2	1.255
4.76	B	91.2	1.255
5.7	B	91.2	1.255
6.0	B	91.2	1.255

TABLE IVa

LEARNING FIGURES

SUBJECT: 14 DATE: Aug. 28
GROUP: 1 SESSION: First

Mean Integrated Error $\|\bar{\epsilon}\|$	TASK	$\ddot{\Delta}$ max	LAG
15.1 mils	A	158 mils/sec^2	0 seconds
	Two-minute-instruction		
7.1	A	158	0
3.55	A	158	0
	One-minute-instruction		
4.7	A	158	0
13.9	B	91.2	1.255
7.35	B	91.2	1.255
6.3	B	91.2	1.255
	Two-minute-instruction		
7.2	B	91.2	1.255
4.7	B	91.2	1.255
3.55	A	158	0
4.75	A	158	0
4.16	A	158	0
4.0	A	158	0
3.8	A	158	0
3.55	A	158	0
7.35	B	91.2	1.255
6.19	B	91.2	1.255
7.35	B	91.2	1.255
12.25	B	91.2	1.255

TABLE IVb

LEARNING FIGURES

SUBJECT: 14 DATE: Aug. 29
GROUP: 1 SESSION: Second

Mean Integrated Error $\overline{|e|}$	TASK	$\ddot{\Delta}$ max	LAG
5.1 mils	A	158 mils/sec^2	0 seconds
	Two-minute-instruction		
4.7	A	158	0
2.65	A	158	0
2.9	A	158	0
3.1	A	158	0
3.45	A	158	0
4.2	A	158	0
	Two-minute-instruction		
5.2	B	91.2	1.255
4.35	B	91.2	1.255
4.6	B	91.2	1.255
	One-minute-instruction		
5.7	B	91.2	1.255
4.1	B	91.2	1.255
AUDITORY SHADOWING			
3.2	A	158	0
4.09 A/S	A	158	0
3.2	A	158	0
5.05	B	91.2	1.255
8.9 A/S	B	91.2	1.255
5.6	B	91.2	1.255

TABLE IVc

LEARNING FIGURES

SUBJECT: 14 DATE: Aug. 29
GROUP: 1 SESSION: Third

Mean Integrated Error $\lvert\bar{\varepsilon}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
10.5 mils	B	91.2 mils/sec^2	1.255 seconds
6.0	B	91.2	1.255
6.0	B	91.2	1.255
6.3	B	91.2	1.255
4.53	B	91.2	1.255
2.66	A	158	0
5.15	A	158	0
3.55	A	158	0
3.37	A	158	0
4.2	A	158	0
9.1	B	91.2	1.255
7.5	B	91.2	1.255
10.7	B	91.2	1.255
4.75	B	91.2	1.255
6.69	B	91.2	1.255

TABLE Va

LEARNING FIGURES

SUBJECT:	15	DATE:	Aug. 26
GROUP:	1	SESSION:	First

Mean Integrated Error $\lvert\bar{E}\rvert$	TASK	$\ddot{A}$ max	LAG
6.01 mils	A	158 mils/sec^2	0 seconds
4.55	A	158	0
5.31	A	158	0
12.6	B	91.2	1.255
12.9	B	91.2	1.255
6.8	B	91.2	1.255
10.0	B	91.2	1.255

TABLE Vb

LEARNING FIGURES

SUBJECT:	15	DATE:	Aug. 28
GROUP:	1	SESSION:	Second

Mean Integrated Error $\overline{|\epsilon|}$	TASK	$\ddot{\Delta}$ max	LAG
4.0 mils	A	158 mils/sec^2	0 seconds
4.08	A	158	0
	One-minute-instruction		
4.25	A	158	0
4.1	A	158	0
	One-minute-instruction		
4.35	A	158	0
	Two-minute-instruction		
9.6	B	91.2	1.255
8.17	B	91.2	1.255

AUDITORY SHADOWING

3.55	A	158	0
7.49 A/S	A	158	0
3.8	A	158	0
7.6	B	91.2	1.255
12.9 A/S		91.2	1.255
9.4	B	91.2	1.255

TABLE Vc

LEARNING FIGURES

SUBJECT: 15 DATE: Aug. 30
GROUP: 1 SESSION: Third

Mean Integrated Error $\overline{|e|}$	TASK	$\ddot{\Delta}$ max	LAG
3.1 mils	A	158 mils/sec^2	0 seconds
3.1	A	158	0
3.1	A	158	0
4.35	A	158	0
3.6	A	158	0
6.1	B	91.2	1.255
5.57	B	91.2	1.255
6.4	B	91.2	1.255
4.1	B	91.2	1.255
6.5	B	91.2	1.255
4.9	B	91.2	1.255
4.2	B	91.2	1.255
3.3	B	91.2	1.255
3.3	B	91.2	1.255
3.4	B	91.2	1.255
2.2	A	158	0
2.6	A	158	0
2.65	A	158	0
2.65	A	158	0
3.00	A	158	0

TABLE VIa

LEARNING FIGURES

SUBJECT:	16	DATE:	Aug. 26
GROUP:	1	SESSION:	First

Mean Integrated Error $\lvert\epsilon\rvert$	TASK	$\ddot{\Delta}$ max	LAG
	Two-minute-instruction		
16.8 mils	A	158 mils/sec^2	0 seconds
19.6	A	158	0
12.4	A	158	0
15.5	A	158	0
16.0	A	158	0
18.1	A	158	0
20.0	A	158	0

TABLE VIb

LEARNING FIGURES

SUBJECT:	16	DATE:	Aug. 27
GROUP:	1	SESSION:	Second

Mean Integrated Error $\|\bar{\epsilon}\|$	TASK	$\ddot{\Delta}$ max	LAG
18.0 mils	A	158 mils/sec^2	0 seconds
12.8	A	158	0
14.6	A	158	0
10.5	A	158	0
10.5	A	158	0
7.9	A	158	0
	Two-minute-instruction		
7.1	A	158	0
5.79	A	158	0
	One-minute-instruction		
5.31	A	158	0
	One-minute-instruction		
4.2	A	158	0

	One-minute-instruction		
29.6	B	91.2	1.255
27.5	B	91.2	1.255
21.7	B	91.2	1.255
20.4	B	91.2	1.255
13.0	B	91.2	1.255
	Three-minute-instruction		
11.7	B	91.2	1.255
10.0	B	91.2	1.255
20.1	B	91.2	1.255
11.0	B	91.2	1.255

TABLE VIc

LEARNING FIGURES

SUBJECT:	16	DATE:	Aug. 30
GROUP:	1	SESSION:	Third

Mean Integrated Error $\lvert\bar{e}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
7.1 mils	A	158 mils/sec^2	0 seconds
6.5	A	158	0
6.59	A	158	0
7.4	A	158	0
6.01	A	158	0
20.7	B	91.2	1.255
23.5	B	91.2	1.255
13.2	B	91.2	1.255
15.5	B	91.2	1.255
18.6	B	91.2	1.255
12.2	B	91.2	1.255
13.4	B	91.2	1.255
13.9	B	91.2	1.255
19.6	B	91.2	1.255
11.7	B	91.2	1.255
5.79	A	158	0
4.35	A	158	0
4.7	A	158	0
5.4	A	158	0
6.82	A	158	0

TABLE VIIa

LEARNING FIGURES

SUBJECT: 17 DATE: Aug. 26
GROUP: 2 SESSION: First

Mean Integrated Error $\overline{\|\epsilon\|}$	TASK	$\ddot{\Delta}$ max	LAG
21.3 mils	A	158 mils/sec^2	0 seconds
	Two-minute-instruction		
7.8	A	158	0
17.0	B	91.2	1.255
12.3	B	91.2	1.255
12.9	B	91.2	1.255
11.9	B	91.2	1.255
9.3	B	91.2	1.255

TABLE VIIb

LEARNING FIGURES

SUBJECT: 17 DATE: Aug. 26
GROUP: 2 SESSION: Second

Mean Integrated Error $\overline{\lvert\epsilon\rvert}$	TASK	$\dot{\Delta}$ max	LAG
5.1 mils	A	158 mils/sec^2	0 seconds
	Two-minute-instruction		
3.7	A	158	0
5.0	A	158	0
3.7	A	158	0
	One-minute-instruction		
3.7	A	158	0
9.3	B	91.2	1.255
7.6	B	91.2	1.255
8.0	B	91.2	1.255
6.7	B	91.2	1.255
	One-minute-instruction		
7.8	B	91.2	1.255
7.8	B	91.2	1.255
7.0	B	91.2	1.255
4.7	B	91.2	1.255
4.3	B	91.2	1.255
5.9	B	91.2	1.255
6.2	B	91.2	1.255
5.1	A	158	0
4.65	A	158	0
5.0	A	158	0
4.65	A	158	0
4.65	A	158	0

TABLE VIIc

LEARNING FIGURES

SUBJECT:	17	DATE:	Aug. 30
GROUP:	2	SESSION:	Third

Mean Integrated Error $\overline{\|\epsilon\|}$	TASK	$\ddot{\Delta}$ max	LAG
4.44 mils	A	158 mils/sec^2	0 seconds
3.9	A	158	0
3.71	A	158	0
4.35	A	158	0
4.35	A	158	0
10.9	B	91.2	1.255
6.7	B	91.2	1.255
5.48	B	91.2	1.255
4.64	B	91.2	1.255
5.02	B	91.2	1.255
AUDITORY SHADOWING			
3.8	A	158	0
5.14 A/S	A	158	0
3.38	A	158	0
4.5	B	91.2	1.255
7.75 A/S	B	91.2	1.255
4.1	B	91.2	1.255

TABLE VIIIa

LEARNING FIGURES

SUBJECT: 18 DATE: Aug. 26
GROUP: 2 SESSION: First

Mean Integrated Error $\overline{\|\epsilon\|}$	TASK	$\ddot{\Delta}$ max	LAG
	One-minute-instruction		
6.58 mils	A	158 mils/sec^2	0 seconds
7.9	A	158	0
5.6	A	158	0
11.3	B	91.2	1.255
8.82	B	91.2	1.255
	One-minute-instruction		
5.05	B	91.2	1.255
7.5	B	91.2	1.255

TABLE VIIIb

LEARNING FIGURES

SUBJECT: 18 DATE: Aug. 27
GROUP: 2 SESSION: Second

Mean Integrated Error $\overline{\|\epsilon\|}$	TASK	$\ddot{\Delta}$ max	LAG
5.6 mils	A	158 mils/sec^2	0 seconds
5.69	A	158	0
	Two-minute-instruction		
5.12	A	158	0
	One-minute-instruction		
4.95	A	158	0
5.12	A	158	0
5.08	A	158	0
	Two-minute-instruction		
4.08	A	158	0
7.9	B	91.2	1.255
5.7	B	91.2	1.255
	One-minute-instruction		
6.51	B	91.2	1.255
6.0	B	91.2	1.255
AUDITORY SHADOWING			
2.85	A	158	0
4.45 A/S	A	158	0
3.72	A	158	0
6.51	B	91.2	1.255
8.7 A/S	B	91.2	1.255
8.41	B	91.2	1.255

TABLE VIIIc

LEARNING FIGURES

SUBJECT:	18	DATE:	Aug. 30
GROUP:	2	SESSION:	Third

Mean Integrated Error $\overline{\lvert\epsilon\rvert}$	TASK	$\ddot{\Delta}$ max	LAG
3.9 mils	A	158 mils/sec^2	0 seconds
3.7	A	158	0
3.29	A	158	0
3.29	A	158	0
3.8	A	158	0
6.67	B	91.2	1.255
6.51	B	91.2	1.255
3.95	B	91.2	1.255
5.18	B	91.2	1.255
5.42	B	91.2	1.255
4.75	B	91.2	1.255
3.4	B	91.2	1.255
2.72	B	91.2	1.255
2.85	B	91.2	1.255
7.5	B	91.2	1.255
3.55	A	158	0
3.36	A	158	0
3.72	A	158	0
3.1	A	158	0
3.45	A	158	0

TABLE IXa

LEARNING FIGURES

SUBJECT:	19	DATE:	Aug. 26
GROUP:	2	SESSION:	First

Mean Integrated Error $\lvert\bar{\epsilon}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
6.11 mils	A	158 mils/sec^2	0 seconds
7.59	A	158	0
9.1	A	158	0
7.62	A	158	0
15.4	B	91.2	1.255
9.25	B	91.2	1.255
16.8	B	91.2	1.255
10.2	B	91.2	1.255

TABLE IXb

LEARNING FIGURES

SUBJECT: 19 DATE: Aug. 27
GROUP: 2 SESSION: Second

Mean Integrated Error $\lvert\epsilon\rvert$	TASK	$\ddot{\Delta}$ max	LAG
7.7 mils	A	158 mils/sec^2	0 seconds
	One-minute-instruction		
7.1	A	158	0
	One-minute-instruction		
5.15	A	158	0
	One-minute-instruction		
5.79	A	158	0
5.5	A	158	0
5.15	A	158	0
	One-minute-instruction		
5.22	A	158	0
10.5	B	91.2	1.255
	Two-minute-instruction		
7.5	B	91.2	1.255
6.0	B	91.2	1.255
8.0	B	91.2	1.255
8.18	B	91.2	1.255
6.8	B	91.2	1.255

TABLE IXc

LEARNING FIGURES

SUBJECT: 19 DATE: Aug. 28
GROUP: 2 SESSION: Third

Mean Integrated Error $\|\bar{\epsilon}\|$	TASK	$\ddot{\Delta}$ max	LAG
4.9 mils	A	158 mils/sec^2	0 seconds
4.7	A	158	0
	One-minute-instruction		
3.72	A	158	0
3.72	A	158	0
3.82	A	158	0
8.3	B	91.2	1.255
7.2	B	91.2	1.255
	One-minute-instruction		
6.0	B	91.2	1.255
5 3	B	91.2	1.255
5.05	B	91.2	1.255
5.18	B	91.2	1.255
AUDITORY SHADOWING			
4.0	A	158	0
5.9 A/S	A	158	0
3.45	A	158	0
5.05	B	91.2	1.255
9.8 A/S	B	91.2	1.255
5.6	B	91.2	1.255

TABLE Xa

LEARNING FIGURES

SUBJECT: 20 DATE: Aug. 26
GROUP: 2 SESSION: First

Mean Integrated Error $\overline{\|\epsilon\|}$	TASK	$\ddot{X}_{max}$	LAG
22.2 mils	A	158 mils/sec^2	0 seconds
16.9	A	158	0
	One-minute-instruction		
13.2	A	158	0
	One-minute-instruction		
10.3	A	158	0
17.3	B	91.2	1.255
11.6	B	91.2	1.255
32.5	B	91.2	1.255
30.0	B	91.2	1.255
	One-minute-instruction		
28.2	B	91.2	1.255
27.2	B	91.2	1.255
9.2	B	91.2	1.255
13.9	B	91.2	1.255

TABLE Xb

LEARNING FIGURES

SUBJECT:	20	DATE:	Aug. 28
GROUP:	2	SESSION:	Second

Mean Integrated Error $\lvert\bar{\epsilon}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
6.8 mils	A	158 mils/sec^2	0 seconds
	One-minute-instruction		
6.8	A	158	0
7.49	A	158	0
6.59	A	158	0
	One-minute-instruction		
7.1	A	158	0
	One-minute-instruction		
14.4	B	91.2	1.255
11.6	B	91.2	1.255
10.2	B	91.2	1.255
	One-minute-instruction		
9.5	B	91.2	1.255
5.55	A	158	0
4.65	A	158	0
4.4	A	158	0
5.95	A	158	0

AUDITORY SHADOWING

Mean Integrated Error $\lvert\bar{\epsilon}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
5.05	A	158	0
14.9 A/S	A	158	0
4.5	A	158	0
11.6	B	91.2	1.255
11.6	B	91.2	1.255
30.0 A/S	B	91.2	1.255
8.0	B	91.2	1.255

TABLE Xc

LEARNING FIGURES

SUBJECT: 20 DATE: Aug. 29
GROUP: 2 SESSION: Third

Mean Integrated Error $|\bar{\epsilon}|$	TASK	$\ddot{\Delta}$ max	LAG
5.5 mils	A	158 mils/sec^2	0 seconds
4.0	A	158	0
4.2	A	158	0
5.08	A	158	0
4.9	A	158	0
4.1	A	158	0
3.81	A	158	0
3.38	A	158	0
4.9	A	158	0
4.36	A	158	0
	Three-minutes-instruction		
7.38	B	91.2	1.255
	Two-minutes-instruction		
6.34	B	91.2	1.255
5.01	B	91.2	1.255
5.7	B	91.2	1.255
4.15	B	91.2	1.255
5.85	B	91.2	1.255
4.55	B	91.2	1.255
5.62	B	91.2	1.255
4.75	B	91.2	1.255
4.2	B	91.2	1.255
3.4	B	91.2	1.255
4.5	B	91.2	1.255
5.4	B	91.2	1.255

TABLE Xd

LEARNING FIGURES

SUBJECT: 20 DATE: Aug. 30
GROUP: 2 SESSION: Fourth

Mean Integrated Error $\lvert\bar{\epsilon}\rvert$	TASK	$\ddot{\Delta}$ max	LAG
3.9 mils	A	158 mils/sec^2	0 seconds
4.8	A	158	0
4.0	A	158	0
7.9	A	158	0
5.25	A	158	0
8.4	B	91.2	1.255
7.75	B	91.2	1.255
10.2	B	91.2	1.255
9.4	B	91.2	1.255
8.7	B	91.2	1.255
3.8	B	91.2	1.255
3.4	B	91.2	1.255
5.7	B	91.2	1.255
7.2	B	91.2	1.255
4.9	B	91.2	1.255
3.65	A	158	0
4.8	A	158	0
3.38	A	158	0
4.1	A	158	0
4.36	A	158	0

TABLE XI

SUMMARIZED RESULTS OF TRAINING

Definitions:

Training Time: "T" minutes is total spent in training on a particular task, including variations of gain

Final Error: $|\bar{\epsilon}|_t$ mils = average error achieved at the end of training

Standard Error: $|\bar{\epsilon}|$ mils = error read off from figure for appropriate stiffness - no lag (subject 1)

Error Ratio: = $|\bar{\epsilon}|_t / |\bar{\epsilon}|$

Task "A" stiffness, $\ddot{\Delta}$max, = 158 mils/sec^2
lag = 0
standard error (Figure 3) = 1.8 mils

Task "B" stiffness, $\ddot{\Delta}$max = 91.2 mils/sec^2
lag = 1.255 secs.
standard error = 1.15 mils
no lag (Figure 3)

Subject	"T" Task "A"	Final Error	Error Ratio	"T" Task "B"	Final Error	Error Ratio
13	29 mins.	3.5 mils	1.9	19 mins.	5.0 mils	4.3
14	29 mins.	3.5 mils	1.9	33 mins	5.4 mils	4.7
15	25 mins.	3.0 mils	1.7	26 mins	4.0 mils	3.5
16	30 mins.	5.0 mils	2.8	20 mins.	10.0 mils	8.7
17	23 mins.	4.0 mils	2.2	24 mins.	4.5 mils	3.9
18	27 mins.	3.4 mils	1.9	24 mins.	5.0 mils	4.3
19	22 mins.	4.0 mils	2.2	21 mins	5.9 mils	5.1
20	36 mins.	4.5 mils	2.5	36 mins.	9.0 mils	7.8

TABLE XIIa

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 13 DATE: Sept. 4
GROUP: 1 SESSION: First

	Mean Integrated Error $\lvert\overline{\epsilon}\rvert$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
			Two-minute-instruction			
Practice	3.1 mils		A	158 mils/sec^2	0 seconds	
Practice	4.35		B	91.2	1.255	
PRE-STRESS	3.29		A	158	0	8:07 p.m.
	3.0		A	158	0	
	3.29		A	158	0	
	3.55		A	158	0	
	3.29		A	158	0	
	4.64		B	91.2	1.255	8:13 p.m.
	3.8		B	91.2	1.255	
	3.95		B	91.2	1.255	
	4.50		B	91.2	1.255	
	4.64		B	91.2	1.255	
STRESS	4.0	(Sh)	A	158	0	8:25 p.m.
	3.29		A	158	0	
	3.29		A	158	0	
	4.0	(Sh)	A	158	0	
	3.45	(Sh)	A	158	0	
	4.35	(Sh)	B	91.2	1.255	8:31 p.m.
	3.67		B	91.2	1.2[illegible]5	
	3.95	(Sh)	B	91.2	1.255	
	4.2	(Sh)	B	91.2	1.255	
	5.03		B	91.2	1.255	
POST-STRESS	2.85		A	158	0	8:39 p.m.
	3.0		A	158	0	
	3.0		A	158	0	
	2.75		A	158	0	
	3.1		A	158	0	
	3.55		B	91.2	1.255	8:45 p.m.
	4.1		B	91.2	1.255	
	3.4		B	91.2	1.255	
	4.2		B	91.2	1.255	
	4.1		B	91.2	1.255	8:50 p.m.

TABLE XIIb

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 13 DATE: Sept. 5
GROUP: 1 SESSION: Second

Mean Integrated Error $\overline{\|\epsilon\|}$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	3.0 mils	A	158 mils/sec^2	0 seconds	
Practice	3.14	B	91.2	1.255	
PRE-STRESS	3.72	B	91.2	1.255	6:10 p.m.
	3.12	B	91.2	1.255	
	4.22	B	91.2	1.255	
	3.26	B	91.2	1.255	
	2.71	B	91.2	1.255	
	2.14	A	158	0	6:16 p.m.
	2.30	A	158	0	
	2.75	A	158	0	
	2.85	A	158	0	
	2.14	A	158	0	
STRESS	12.4 A/S	B	91.2	1.255	6:25 p.m.
	3.12	B	91.2	1.255	
	6.40 A/S	B	91.2	1.255	
	9.80 A/S	B	91.2	1.255	
	2.71	B	91.2	1.255	
	4.10 A/S	A	158	0	6:32 p.m.
	2.05	A	158	0	
	2.21	A	158	0	
	3.30	A	158	0	
	3.81 A/S	A	158	0	
POST-STRESS	3.0	B	91.2	1.255	6:39 p.m.
	2.60	B	91.2	1.255	
	3.12	B	91.2	1.255	
	2.71	B	91.2	1.255	
	2.71	B	91.2	1.255	
	1.96	A	158	0	6:45 p.m.
	1.96	A	158	0	
	2.4	A	158	0	
	2.66	A	158	0	

TABLE XIIIa

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 14 DATE: Sept. 5
GROUP: 1 SESSION: First

Mean Integrated Error $\|\bar{\epsilon}\|$			TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	3.3 mils		A	158 mils/sec^2	0 seconds	
"	3.3		A	158	0	
			One-minute-instruction			
Practice	3.3		A	158	0	
"	6.3		B	91.2	1.255	
			One-minute-instruction			
Practice	5.3		B	91.2	1.255	
PRE-STRESS	3.45		A	158	0	3:22 p.m.
	2.58		A	158	0	
	3.29		A	158	0	
	2.58		A	158	0	
	3.1		A	158	0	
	5.3		B	91.2	1.255	3:28 p.m.
	4.5		B	91.2	1.255	
	4.08		B	91.2	1.255	
	3.55		B	91.2	1.255	
	4.35		B	91.2	1.255	
STRESS	2.6	(Sh)	A	158	0	3:40 p.m.
	1.96		A	158	0	
	2.75		A	158	0	
	2.5	(Sh)	A	158	0	
	2.65	(Sh)	A	158	0	
	4.2	(Sh)	B	91.2	1.255	3:47 p.m.
	4.35		B	91.2	1.255	
	3.4	(Sh)	B	91.2	1.255	
	4.5	(Sh)	B	91.2	1.255	
	4.08		B	91.2	1.255	
POST-STRESS	3.36		A	158	0	3:54 p.m.
	2.75		A	158	0	
	2.65		A	158	0	
	2.65		A	158	0	
	4.35		A	158	0	
	6.1		B	91.2	1.255	4:01 p.m.
	3.95		B	91.2	1.255	
	5.3		B	91.2	1.255	
	4.08		B	91.2	1.255	
	5.42		B	91.2	1.255	

TABLE XIIIb

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 14 DATE: Sept. 6
GROUP: 1 SESSION: Second

Mean Integrated Error $\|\varepsilon\|$		TASK	$\ddot{A}$ max.	LAG	TIME
Practice	4.08 mils	B	91.2 mils/sec^2	1.255 sec.	
Practice	2.84	A	158	0	
PRE-STRESS	4.64	B	91.2	1.255	3:10 p.m.
	4 9	B	91.2	1.255	
	3.69	B	91.2	1.255	
	3.26	B	91.2	1.255	
	2.72	B	91.2	1.255	
	3.1	A	158	0	3:16 p.m.
	2.58	A	158	0	
	2.58	A	158	0	
	2.65	A	158	0	
	3.2	A	158	0	
STRESS	20.1 A/S	B	91.2	1.255	3:33 p.m.
	4.75	B	91.2	1.255	
	7.31 A/S	B	91.2	1.255	
	7.2 A/S	B	91.2	1.255	
	3.8	B	91.2	1.255	
	3.64 A/S	A	158	0	3:40 p.m.
	3.45	A	158	0	
	2.85	A	158	0	
	3.45 A/S	A	158	0	
	2.85 A/S	A	158	0	
POST-STRESS	3.25	B	91.2	1.255	3:47 p.m.
	3.54	B	91.2	1.255	
	4.2	B	91.2	1.255	
	3.67	B	91.2	1.255	
	3.67	B	91.2	1.255	
	1.95	A	158	0	3:53 p.m.
	3.0	A	158	0	
	3.72	A	158	0	
	2.3	A	158	0	
	2.58	A	158	0	

TABLE XIVa

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 15 DATE: Sept. 5
GROUP: 1 SESSION: First

	Mean Integrated Error $|\overline{\epsilon}|$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	3.2 mils		A	158 mils/sec^2	0 sec.	
	4.16		A	158	0	
	3.64		A	158	0	
	3.29		A	158	0	
	6.51		A	158	0	
Practice	3.86		B	91.2	1.255	
	3.80		B	91.2	1.255	
	4.3		B	91.2	1.255	
	3.55		B	91.2	1.255	
	3.95		B	91.2	1.255	
	3.95		B	91.2	1.255	
	2.92		A	158	0	9:45 a.m.
PRE-STRESS	2.85		A	158	0	
	2.66		A	158	0	
	3.2		A	158	0	
	2.94		A	158	0	
	3.67		B	91.2	1.255	9:50 a.m.
	3.55		B	91.2	1.255	
	4.1		B	91.2	1.255	
	3.80		B	91.2	1.255	
	3.80		B	91.2	1.255	
	3.9	(Sh)	A	158	0	10:01 a.m.
STRESS	2.05		A	158	0	
	2.49		A	158	0	
	2.85	(Sh)	A	158	0	
	2.4	(Sh)	A	158	0	
	3.4	(Sh)	B	91.2	1.255	10:07 a.m.
	3.15		B	91.2	1.255	
	3.15	(Sh)	B	91.2	1.255	
	2.85	(Sh)	B	91.2	1.255	
	2.85		B	91.2	1.255	
	2.65		A	158	0	10:13 a.m.
POST-STRESS	2.65		A	158	0	
	2.57		A	158	0	
	3.1		A	158	0	
	2.4		A	158	0	
	3.0		B	91.2	1.255	10:20 a.m.
	11.7		B	91.2	1.255	
	5.3		B	91.2	1.255	
	2.85		B	91.2	1.255	
	3.8		B	91.2	1.255	

TABLE XIVb

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 15 DATE: Sept. 6
GROUP: 1 SESSION: Second

	Mean Integrated Error $\overline{\|\epsilon\|}$	TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	3.0 mils	B	91.2 mils/sec^2	1.255 sec.	
Practice	2.65	A	158	0	
PRE-STRESS	4.07	B	91.2	1.255	9:24 a.m.
	6.9	B	91.2	1.255	
	6.5	B	91.2	1.255	
	5.4	B	91.2	1.255	
	5.85	B	91.2	1.255	
	2.49	A	158	0	9:30 a.m.
	2.21	A	158	0	
	2.75	A	158	0	
	2.49	A	158	0	
	2.4	A	158	0	
STRESS	11.80 A/S	B	91.2	1.255	9:39 a.m.
	4.10	B	91.2	1.255	
	8.85 A/S	B	91.2	1.255	
	4.50 A/S	B	91.2	1.255	
	4.50	B	91.2	1.255	
	2.75 A/S	A	158	0	9:46 a.m.
	2.5	A	158	0	
	2.4	A	158	0	
	3.45 A/S	A	158	0	
	3.36 A/S	A	158	0	
POST-STRESS	2.21	B	91.2	1.255	9:53 a.m.
	3.12	B	91.2	1.255	
	2.45	B	91.2	1.255	
	2.45	B	91.2	1.255	
	2.85	B	91.2	1.255	
	2.94	A	158	0	9:59 a.m.
	3.90	A	158	0	
	1.96	A	158	0	
	2.57	A	158	0	
	3.36	A	158	0	

TABLE XVa

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 16 DATE: Sept. 3
GROUP: 1 SESSION: First

	Mean Integrated Error $\|\overline{\epsilon}\|$	TASK	$\ddot{\delta}$ max.	LAG	TIME
Practice	5.05 mils	A	158 mils/sec^2	0 sec.	3:08 p.m.
			One-minute-instruction		
	4.25	A	158	0	
	6.8	B	91.2	1.255	
PRE-STRESS	4.6	A	158	0	3:20 p.m.
	5.13	A	158	0	
	4.51	A	158	0	
	4.1	A	158	0	
	4.7	A	158	0	
	6.68	B	91.2	1.255	3:26 p.m.
	8.7	B	91.2	1.255	
	8.84	B	91.2	1.255	
	10.5	B	91.2	1.255	
	8.19	B	91.2	1.255	
STRESS	4.61 (Sh)	A	158	0	3:39 p.m.
	4.95	A	158	0	
	3.64	A	158	0	
	4.1 (Sh)	A	158	0	
	3.2 (Sh)	A	158	0	
	9.5 (Sh)	B	91.2	1.255	3:46 p.m.
	8.49	B	91.2	1.255	
	17.3 (Sh)	B	91.2	1.255	
	12.5 (Sh)	B	91.2	1.255	
	12.2	B	91.2	1.255	
POST-STRESS	4.35	A	158	0	3:51 p.m.
	4.35	A	158	0	
	5.08	A	158	0	
	4.53	A	158	0	
	5.25	A	158	0	
	10.6	B	91.2	1.255	3:58 p.m.
	10.2	B	91.2	1.255	
	10.0	B	91.2	1.255	
	10.0	B	91.2	1.255	
	14.6	B	91.2	1.255	

TABLE XVb

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 16 DATE: Sept. 4
GROUP: 1 SESSION: Second

	Mean Integrated Error $\|\epsilon\|$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
PRE-STRESS	8.3 mils		B	91.2 mils/sec^2	1.255 sec.	4:29 p.m.
	18.8		B	91.2	1.255	
	9.65		B	91.2	1.255	
	8.3		B	91.2	1.255	
	11.8		B	91.2	1.255	
	3.8		A	158	0	4:34 p.m.
	5.4		A	158	0	
	6.12		A	158	0	
	10.2		A	158	0	
	4.61		A	158	0	
STRESS	9.65	A/S	B	91.2	1.255	4:45 p.m.
	9.4		B	91.2	1.255	
	14.8	A/S	B	91.2	1.255	
	12.4	A/S	B	91.2	1.255	
	11.0		B	91.2	1.255	
	5.25	A/S	A	158	0	4:53 p.m.
	4.96		A	158	0	
	5.25		A	158	0	
	6.6	A/S	A	158	0	
	7.2		A	158	0	
POST-STRESS	11.0		B	91.2	1.255	4:59 p.m.
	9.21		B	91.2	1.255	
	8.99		B	91.2	1.255	
	11.0		B	91.2	1.255	
	13.41		B	91.2	1.255	
	4.35		A	158	0	5:06 p.m.
	4.96		A	158	0	
	7.0		A	158	0	
	7.49		A	158	0	
	5.25		A	158	0	

TABLE XVIa

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 17 DATE: Sept. 5
GROUP: 2 SESSION: First

	Mean Integrated Error |ε|		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	3.36 mils		A	158 mils/sec²	0 seconds	
	5.87		B	91.2	1.255	
				One-minute-instruction		
Practice	5.59		B	91.2	1.255	
	2.92		A	158	0	11:46 a.m
PRE-STRESS	2.75		A	158	0	
	3.1		A	158	0	
	3.29		A	158	0	
	3.0		A	158	0	
	5.0		B	91.2	1.255	11:53 a.m
	4.5		B	91.2	1.255	
	3.8		B	91.2	1.255	
	4.63		B	91.2	1.255	
	3.8		B	91.2	1.255	
	4.1	A/S	A	158	0	12:01 p.m
STRESS	3.2		A	158	0	
	2.84		A	158	0	
	5.14	A/S	A	158	0	
	4.6	A/S	A	158	0	
	11.2	A/S	B	91.2	1.255	12:08 p.m
	4.6		B	91.2	1.255	
	9.1	A/S	B	91.2	1.255	
	6.5	A/S	B	91.2	1.255	
	3.27		B	91.2	1.255	
POST-STRESS	2.49		A	158	0	12:14 p.m
	3.0		A	158	0	
	3.9		A	158	0	
	3.37		A	158	0	
	3.45		A	158	0	
	5.19		B	91.2	1.255	12:20 p.m
	2.85		B	91.2	1.255	
	3.55		B	91.2	1.255	
	3.40		B	91.2	1.255	
	4.64		B	91.2	1.255	

TABLE XVIb

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 17 DATE: Sept. 6
GROUP: 2 SESSION: Second

Mean Integrated Error $\overline{\epsilon}$			TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	4.2 mils		B	91.2 mils/sec^2	1.255 sec.	
Practice	2.66		A	158	0	
PRE-STRESS	3.4		B	91.2	1.255	11:51 a.m.
	4.1		B	91.2	1.255	
	3.4		B	91.2	1.255	
	3.66		B	91.2	1.255	
	3.54		B	91.2	1.255	
	3.0		A	158	0	11:57 a.m.
	3.45		A	158	0	
	3.1		A	158	0	
	3.65		A	158	0	
	3.3		A	158	0	
STRESS	6.28	(Sh)	B	91.2	1.255	12:14 p.m.
	3.0		B	91.2	1.255	
	3.27	(Sh)	B	91.2	1.255	
	3.27	(Sh)	B	91.2	1.255	
	3.0		B	91.2	1.255	
	2.4	(Sh)	A	158	0	12:20 p.m.
	2.49		A	158	0	
	2.84		A	158	0	
	2.84	(Sh)	A	158	0	
	2.65	(Sh)	A	158	0	
POST-STRESS	3.95		B	91.2	1.255	12:27 p.m.
	3.27		B	91.2	1.255	
	3.0		B	91.2	1.255	
	2.85		B	91.2	1.255	
	2.30		B	91.2	1.255	
	2.40		A	158	0	12:34 p.m.
	2.94		A	158	0	
	2.65		A	158	0	
	3.02		A	158	0	
	2.84		A	158	0	

TABLE XVIIa

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 18 DATE: Sept. 3
GROUP: 2 SESSION: First

	Mean Integrated Error $\lvert\tilde{\epsilon}\rvert$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	4.17 mils		A	158 mils/sec^2	0 sec.	4:15 p.m.
				One-minute-instruction		
Practice	2.75		A	158	0	
Practice	6.7		B	91.2	1.255	
				One-minute-instruction		
	5.3		B	91.2	1.255	
PRE-STRESS	2.94		A	158	0	4:24 p.m.
	2.57		A	158	0	
	2.49		A	158	0	
	3.01		A	158	0	
	3.01		A	158	0	
	3.71		A	158	0	
	4.76		B	91.2	1.255	4:31 p.m.
	3.69		B	91.2	1.255	
	3.55		B	91.2	1.255	
	4.1		B	91.2	1.255	
	4.1		B	91.2	1.255	
STRESS	3.9	A/S	A	158	0	4:42 p.m.
	2.4		A	158	0	
	2.3		A	158	0	
	2.9	A/S	A	158	0	
	3.2	A/S	A	158	0	
	5.85	A/S	B	91.2	1.2[illegible]	4:50 p.m.
	3.14		B	91.2	1.255	
	4.64	A/S	B	91.2	1.255	
	5.3	A/S	B	91.2	1.255	
	3.55		B	91.2	1.255	
POST-STRESS	2.49		A	158	0	4:56 p.m.
	2.49		A	158	0	
	2.75		A	158	0	
	2.85		A	158	0	
	3.2		A	158	0	
	3.95		B	91.2	1.255	5:04 p.m.
	3.69		B	91.2	1.255	
	3.8		B	91.2	1.255	
	3.69		B	91.2	1.255	
	4.1		B	91.2	1.255	

TABLE XVIIb

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 18 DATE: Sept. 4
GROUP: 2 SESSION: Second

	Mean Integrated Error $\overline{\|e\|}$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	4.75 mils		B	91.2 mils/sec^2	1.255 sec.	
			One-minute-instruction			
Practice	4.07		B	91.2	1.255	
Practice	3.2		A	158	0	
PRE-STRESS	4.9		B	91.2	1.255	5:28 p.m.
	5.7		B	91.2	1.255	
	2.58		B	91.2	1.255	
	2.58		B	91.2	1.255	
	2.85		B	91.2	1.255	
	2.66		A	158	0	5:34 p.m.
	2.3		A	158	0	
	2.49		A	158	0	
	2.61		A	158	0	
	2.75		A	158	0	
STRESS	3.55	(Sh)	B	91.2	1.255	5:44 p.m.
	2.72		B	91.2	1.255	
	3.26	(Sh)	B	91.2	1.255	
	3.14	(Sh)	B	91.2	1.255	
	2.45		B	91.2	1.255	
	2.13	(Sh)	A	158	0	5:51 p.m.
	2.13		A	158	0	
	1.95		A	158	0	
	2.49	(Sh)	A	158	0	
	2.49	(Sh)	A	158	0	
POST-STRESS	3.14		B	91.2	1.255	5:58 p.m.
	3.14		B	91.2	1.255	
	2.85		B	91.2	1.255	
	2.45		B	91.2	1.255	
	2.72		B	91.2	1.255	
	2.49		A	158	0	6:05 p.m.
	2.05		A	158	0	
	2.3		A	158	0	
	2.22		A	158	0	
	2.3		A	158	0	

TABLE XVIIIa

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 19 DATE: Sept. 4
GROUP: 2 SESSION: First

	Mean Integrated Error $\bar{E}$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	4.17 mils		A	158 mils/sec^2	0 sec.	2:12 p.m.
Practice	3.64		A	158	0	
Practice	6.8		B	91.2	1.255	
			One-minute-instruction			
	5.45		B	91.2	1.255	
PRE-STRESS	3.55		A	158	0	2:23 p.m.
	4.0		A	158	0	
	4.5		A	158	0	
	4.0		A	158	0	
	3.71		A	158	0	
	5.3		B	91.2	1.255	2:28 p.m.
	4.35		B	91.2	1.255	
	5.02		B	91.2	1.255	
	6.4		B	91.2	1.255	
	5.3		B	91.2	1.255	
STRESS	5.05	A/S	A	158	0	2:39 p.m.
	3.45		A	158	0	
	3.64		A	158	0	
	4.87	A/S	A	158	0	
	6.3	A/S	A	158	0	
	7.62	A/S	B	91.2	1.255	2:45 p.m.
	5.6		B	91.2	1.255	
	10.6	A/S	B	91.2	1.255	
	8.7	A/S	B	91.2	1.255	
	6.4		B	91.2	1.255	
POST-STRESS	3.45		A	158	0	2:51 p.m.
	4.0		A	158	0	
	3.71		A	158	0	
	4.25		A	158	0	
	3.45		A	158	0	
	3.76		B	91.2	1.255	2:58 p.m.
	5.46		B	91.2	1.255	
	3.76		B	91.2	1.255	
	4.35		B	91.2	1.255	
	4.5		B	91.2	1.255	

TABLE XVIIIb

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 19 DATE: Sept. 5
GROUP: 2 SESSION: Second

	Mean Integrated Error $|\bar{\varepsilon}|$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	3.4 mils		A	158 mils/sec^2	0 sec.	
Practice	3.0		B	91.2	1.255	
PRE-STRESS	3.25		B	91.2	1.255	2:11 p.m.
	4.06		B	91.2	1.255	
	3.95		B	91.2	1.255	
	4.35		B	91.2	1.255	
	4.35		B	91.2	1.255	
	3.0		A	158	0	2:17 p.m.
	2.92		A	158	0	
	3.1		A	158	0	
	2.75		A	158	0	
	3.45		A	158	0	
STRESS	3.0	(Sh)	B	91.2	1.255	2:27 p.m.
	3.4		B	91.2	1.255	
	3.25	(Sh)	B	91.2	1.255	
	3.0	(Sh)	B	91.2	1.255	
	3.0		B	91.2	1.255	
	3.0	(Sh)	A	158	0	2:33 p.m.
	2.75		A	158	0	
	3.3		A	158	0	
	2.92	(Sh)	A	158	0	
	3.45	(Sh)	A	158	0	
POST-STRESS	2.31		B	91.2	1.255	2:41 p.m.
	2.59		B	91.2	1.255	
	2.31		B	91.2	1.255	
	2.72		B	91.2	1.255	
	2.31		B	91.2	1.255	
	2.49		A	158	0	2:47 p.m.
	2.57		A	158	0	
	2.92		A	158	0	
	2.65		A	158	0	
	2.92		A	158	0	

TABLE XIXa

EXPERIMENTAL RESULTS - AUDITORY SHADOWING

SUBJECT: 20 DATE: Sept. 4
GROUP: 2 SESSION: First

	Mean Integrated Error $\lvert\bar{\epsilon}\rvert$		TASK	$\ddot{\Delta}$ max.	LAG	TIME
Practice	4.7 mils		A	158 mils/sec^2	0 sec.	10:01 a.m.
			One-minute-instruction			
Practice	4.95		A	158	0	
Practice	12.4		B	91.2	1.255	
Practice	6.9		B	91.2	1.255	
PRE-	5.14		A	158	0	10:11 a.m.
STRESS	4.35		A	158	0	
	4.15		A	158	0	
	5.05		A	158	0	
	5.75		A	158	0	
	8.7		B	91.2	1.255	10:21 a.m.
	6.25		B	91.2	1.255	
	6.51		B	91.2	1.255	
	6.0		B	91.2	1.255	
	6.25		B	91.2	1.255	
	9.5	A/S	A	158	0	10:30 a.m.
STRESS	5.22		A	158	0	
	3.55		A	158	0	
	6.9	A/S	A	158	0	
	6.4	A/S	A	158	0	
	17.8	A/S	B	91.2	1.255	10:37 a.m.
	6.25		B	91.2	1.255	
	24.8	A/S	B	91.2	1.255	
	22.7	A/S	B	91.2	1.255	
	7.9		B	91.2	1.255	
	4.16		A	158	0	10:44 a.m.
POST-	3.45		A	158	0	
STRESS	3.9		A	158	0	
	3.55		A	158	0	
	3.45		A	158	0	
	6.0		B	91.2	1.255	10:50 a.m.
	5.45		B	91.2	1.255	
	6.1		B	91.2	1.255	
	7.09		B	91.2	1.255	
	6.1		B	91.2	1.255	

TABLE XIXb

EXPERIMENTAL RESULTS - ELECTRIC SHOCK

SUBJECT: 20 DATE: Sept. 5
GROUP: 2 SESSION: Second

Mean Integrated Error $\overline{\|\epsilon\|}$			TASK	$\ddot{A}$ max.	LAG	TIME
Practice	5.3 mils		B	91.2 mils/sec^2	1.255 sec.	
Practice	3.2		A	158	0	
PRE-STRESS	3.95		B	91.2	1.255	10:40 a.m.
	4.6		B	91.2	1.255	
	4.9		B	91.2	1.255	
	4.9		B	91.2	1.255	
	4.35		B	91.2	1.255	
	2.94		A	158	0	10:47 a.m.
	2.94		A	158	0	
	2.94		A	158	0	
	3.8		A	158	0	
	2.57		A	158	0	
STRESS	4.06	(Sh)	B	91.2	1.255	10:58 a.m.
	3.0		B	91.2	1.255	
	3.14	(Sh)	B	91.2	1.255	
	4.2	(Sh)	B	91.2	1.255	
	4.06	(Sh)	B	91.2	1.255	
	1.51	(Sh)	A	158	0	11:05 a.m.
	3.2		A	158	0	
	1.78		A	158	0	
	1.51	(Sh)	A	158	0	
	2.3	(Sh)	A	158	0	
POST-STRESS	2.59		B	91.2	1.255	11:17 a.m.
	3.0		B	91.2	1.255	
	2.45		B	91.2	1.255	
	6.0		B	91.2	1.255	
	2.18		B	91.2	1.255	
	2.04		A	158	0	11:24 a.m.
	2.85		A	158	0	
	2.4		A	158	0	
	3.2		A	158	0	
	2.66		A	158	0	

TABLE XX

SUMMARIZED TRACKING RESULTS (with auditory shadowing as stressor)

Subject	Tracking Task	Base Level*	MEAN MODULAR ERRORS (mils), $\lvert\bar{\epsilon}\rvert$			
			Pre-Stress**	Stressed+	Not-Stressed++	Post-Stress**
Group I						
13	B	5.0	3.40	9.53	2.91	2.82
	A	3.65	2.44	3.73	2.13	2.19
14	B	5.4	3.84	11.53	4.27	3.66
	A	3.5	2.82	3.31	3.15	2.71
15	B	4.0	5.7	8.38	4.30	2.61
	A	3.0	2.46	3.18	2.45	2.94
16	B	10.0	11.37	12.28	10.2	10.72
	A	5.0	6.02	6.35	5.10	5.81
Group II						
17	A	4.0	3.01	4.61	3.02	3.24
	B	4.5	4.34	8.90	3.93	3.92
18	A	3.4	2.95	3.33	2.35	2.75
	B	5.0	4.04	5.27	3.34	3.84
19	A	4.0	3.95	5.40	3.54	3.75
	B	5.9	5.27	8.97	6.00	4.36
20	A	4.5	4.88	7.60	4.38	3.97
	B	9.0	6.74	21.7	7.07	6.14

* Judged from training runs

** Average over 5 one-minute runs

\+ Average of three one-minute runs

++ Average of two one-minute runs

TABLE XXI

SUMMARIZED TRACKING RESULTS (with electric shock as stressor)

Subject	Tracking Task	Base Level*	MEAN MODULAR ERRORS (mils), $\lvert\bar{\epsilon}\rvert$ Pre-Stress**	Stressed+	Not-Stressed++	Post-Stress**
Group I						
13	A	3.5	3.28	3.8	3.29	2.94
	B	5.0	4.30	4.10	4.35	3.87
14	A	3.5	3.0	2.58	2.35	2.15
	B	5.4	4.35	4.03	4.21	4.97
15	A	3.0	2.91	3.05	2.27	2.67
	B	4.0	3.78	3.13	3.00	5.33
16	A	5.0	4.78	3.97	4.29	4.71
	B	10.0	8.58	13.10	10.34	11.08
Group II						
17	B	4.5	3.62	3.76	3.0	3.07
	A	4.0	3.30	2.64	2.66	2.77
18	B	5.0	3.72	3.31	2.58	2.86
	A	3.4	2.56	2.37	2.04	2.27
19	B	5.9	3.99	3.08	3.2	2.44
	A	4.0	3.04	3.12	3.02	2.71
20	B	9.0	4.54	3.80	3.53	3.24
	A	4.5	3.01	1.77	2.49	2.63

* Judged from training runs

** Average over 5 one-minute runs

\+ Average of three one-minute runs

++ Average of two one-minute runs

TABLE XXII

SMOOTHING OF COMBINED AUDITORY SHADOWING AND TRACKING RESULTS

		RAW DATA						SMOOTHED DATA			
S		$\lvert\bar{\epsilon}\rvert_o^*$	N_o	$\lvert\bar{\epsilon}\rvert_S^{**}$	E^+	δ	A/S^x	δ'	A/S'	E'	Stress Level**
13	A	2.31	387	3.73	1.62	15.0	5	10.0	10.0	1.41	.41
	B	3.11	253	9.53	3.07	32.7	12	22.4	22.4	2.42	.43
14	A	2.76	354	3.31	1.20	4.4	14	9.2	9.2	1.42	.42
	B	3.75	231	11.5	3.07	29.9	15	22.2	22.2	2.54	.46
15	A	2.70	358	3.18	1.18	4.0	2	3.0	3.0	1.13	.13
	B	4.20	217	8.38	2.00	13.6	5	9.3	9.3	1.69	.21
16	A	5.91	242	6.35	1.06	0.9	7	4.0	4.0	1.26	.26
	B	11.10	135	12.3	1.11	0.9	12	6.5	6.5	1.73	.22
17	A	3.12	333	4.61	1.48	10.0	9	9.5	9.5	1.46	.46
	B	4.16	219	8.90	2.14	15.6	25	20.3	20.3	2.48	.48
18	A	2.85	349	3.33	1.17	3.7	5	4.4	4.4	1.20	.20
	B	3.94	225	5.27	1.34	4.8	20	12.4	12.4	1.88	.26
19	A	3.85	299	5.40	1.40	7.5	8	7.8	7.8	1.42	.42
	B	4.82	203	8.97	1.86	10.9	16	13.5	13.5	2.06	.32
20	A	4.42	280	7.60	1.72	12.6	13.5	13.1	13.1	1.75	.75
	B	6.44	176	21.7	3.37	26.1	15	20.6	20.6	2.87	.56

* Average of 5 Post-Stress and 5 Pre-Stress runs.

** Average of 3 runs with A/S as a stressor.

x Total errors for 3 stressed runs from tape record of Subject's response (over 162 seconds). (Average of 2 checks)

xx Assumed equal to $(E'-1)$ for Task A, $0.3(E'-1)$ for Task B.

\+ $E = |\bar{\epsilon}|_S / |\bar{\epsilon}|_o$

APPENDIX I

THE NATURE OF "STRESS AS EXEMPLIFIED BY VARIOUS DEFINITIONS AND CONCEPTUALIZATIONS:

A Preliminary Paper Prepared In Conjunction With A Research Project Employing A Zero Input Tracking Analyzer (ZITA) As An Indicator of Stress.

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The purpose of this paper is to briefly review some of the conceptual and theoretical approaches employed by various writers in their definitions of "stress", in the attempt to devise an approach to "stress" which may be usefully employed in a research project employing a zero input tracking analyzer (ZITA) as an indicator of stress.

Although a perusal of the literature might cause the reader to conclude that there are several different ways of viewing "stress" as indicated by the various conceptions and definitions of the term, a closer scrutiny reveals that there are common aspects underlying these theoretical frameworks. The definitions cited below exemplify the phenotypically different but, as the writer will attempt to show, genotypically similar theoretical conceptualizations of stress.

Pronko and Leith (Ref. 10 p. 207) have submitted, "Stress is a recent import from physics and engineering and more recently from biological inquiry. For that reason, it does not yet have a fixed usage in behavioral investigation. We have found it used to refer (a) to behavior itself, as in the phrase, 'behavior under stress', (b) to a stimulus, as in 'stressful stimulus', or (c) to a stressful situation, as in 'the laboratory induction of stress.' Our own preference is for its usage in the last sense. The term, stress, then, will be used in this study to designate a set of conditions surrounding a behaving organism. It will be considered as synonomous with such setting factors as are related to the disintegration of the behavioral response configuration of the organism."

Other writers' conceptualizations may be conveniently categorized according to Pronko and Leith's framework. For example, under (c) above would go Schaffer's (Ref. 11p. 332) statement that, "A stressful situation may be described as one in which a major disruption of the relation of the organism to its environment has taken place; it is brought about when a highly motivated organism is unable to find an adjustive response to the problem confronting it."

Fuller (Ref. 12) defined a stressful situation as one in which adjustment is difficult or impossible, but in which motivation is very strong.

Emphasizing the stressful situation, Lazarus et al. (Ref. 7 , p. 295) first defined stress as, "really a secondary concept, built upon the relationship between a primary concept, motivation, and the situation in which motivated behavior appears. We would then think that stress occurs when a particular situation threatens the attainment of some goal." and later (Ref. 13, p. 22) elaborated on this definition as follows: "Psychological stress occurs when a situation is perceived as thwarting or as potentially thwarting to some motive state, thus resulting in affective arousal and in the elicitation of regulative processes aimed at the management of the affect."

It is of interest to note that Lazarus et al. (Ref.14 , p. 100) have, like Pronko and Leith in (c) above, also recognized the usefulness of the operational definition, "One possible criterion of having stress S*s* is an operational one, that is, producing some change in performance which can only be attributed to the stress condition itself."

If one considers a drive to be a stressful stimulus, then Chile's (Ref. 15) position could be placed under (b) above, for he, in putting forth a systematic framework to be employed in the quantification of psychological stress, regarded its (stress') role as that of an irrelevant drive which increases those behavior tendencies present by contributing to the overall level of motivation.

If physiological conceptions of stress are regarded as having potential behavioral observability, then Selye's (Ref. 16) view of stress may be categorized under (a) above, for he regards stress as a condition which functions to facilitate the restoration of the organism to its normal homeostatic state, the reaction involved being designated as the "general adaption syndrome." But let the good doctor speak for himself:" . . . the bodily changes produced, whether the person is exposed to nervous tension, physical injury, infection, cold, hear, X-rays, or anything else, are what we call stress . . . In my earlier writings I had defined stress, somewhat more simply but less precisely, as 'the sum of all nonspecific changes caused by function or damage' or 'the rate of wear and tear in the body.' "Stress is the state manifested by a specific syndrome which consists of all the nonspecifically induced changes within a biologic system."

Basowitz, et al. (Ref. 17, p. 7), also emphasizing the homeostatic aspect, have defined stress as "the threat to the fulfillment of: basic needs, the maintenance of regulated (homeostatic) functioning, and to growth and development."

Katchmar (Ref. 18), also employing a physiological orientation, defined stress as, "...an internal process of the organism, manifested as an equilibrium seeking response, occurring in the psychological context when the objective situation is cognitively evaluated as one involving a goal, the attainment of which is thwarted or interpreted as being thwarted."

Finally, Darrow and Henry (Ref. 19) have argued that an individual is stressed when his responses are no longer appropriate to the situation at hand.

In an attempt to "cut across" these conceptualizations and isolate the factors common to all these approaches, the present writer would concur with Klier and Linskey (Ref. 20, p. 4) that, in regard to the above definitions, "one may discern two common presumptions which are explicitly or implicitly stated. First, it is assumed that something, either actual or imagined, is wrong with the relation between the individual and the environment. Second, the individual is motivated to restore the desired relationship."

These two points can be thought of in terms of the concept of homeostasis. Although this is essentially a physiological concept, i.e., the self-regulatory processes of the body aimed at restoring a state of equilibrium, stress may be conceived as aimed at 'psychological homeostasis.' Thus, the individual perceives a disequilibrium in the situational environment; in some manner his sense of well-being is disturbed, and his subsequent behavior is directed toward restoring this equilibrium.

The concept of "psychological homeostasis" has been discussed by Lazarus, et al (Ref. 7 , p. 295) within the framework of a "motivational component" as it relates to the thwarting of motivated behavior. "Physiological stress does not seem to involve the same definitional problems that psychological stress does, because the 'motivational component' in physiological stress is stated in terms of the well worked out mechanisms of homeostasis... The psychologist has no adequate way of defining the psychological condition that corresponds to the homeostatic steady state ...when we speak of tension-systems, what we are really doing is postulating a psychological state as a lack of tension. What needs to be investigated are the properties of such a state and deviations from it."

As Klier and Linskey have noted, "there does appear to be a basic definition of stress in terms of a disturbing condition which impels an individual to restore some sort of desirable balance or equilibrium between himself and the situational environment, either by a general rise in his level of motivation or by changing specific behavior modes so as to make his responses more suitable."

In conclusion, the writer would like to point out that there has been no mention here of the relationship between stress and various personality variables. Were the present interest focused on individual differences in reactions to stress, then the inclusion of relevant variables in the discussion would be mandatory, for, as Lazarus and his colleagues have repeatedly pointed out, one of the most prevalent findings in "stress" experiments is that reaction to stress is characterized by a host of individual differences. In view of this, the writer points out that the neglect of personality variables is due to the belief that the formulation of an exploratory experimental program (such as is being undertaken by employing ZITA) designed to investigate the use of a tracking task as an indicator of stress requires emphasis on the nomothetic as opposed to the idiographic approach, i.e., on how most people react, not on how any particular individual reacts.

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